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LAND TREATMENT OF SEWAGE

BY

HERBERT T. SCOBLE



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LAND TREATMENT OF SEWAGE.

A DIGEST
of the Reports made to
The Royal Commission on Sewage Disposal
by their specially-appointed officers.

BY

HERBERT T. SCOBLE,

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Member of the Royal Sanitary Institute,
Fellow of the Royal Meteorological Society.

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"The Surveyor and Municipal and County Engineer."



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INTRODUCTORY.

Objects of Royal Commission.

The sitting Royal Commission on Sewage Disposal was appointed in May, 1898, "to inquire and report I. (1) What method or methods of treating and disposing of sewage (including any liquid from any factory or manufacturing process) may properly be adopted, consistently with due regard for the requirements of the existing law, for the protection of the public health, and for the economical and efficient discharge of the duties of local authorities; and (2) if more than one method may be so adopted, by what rules, in relation to the nature or volume of sewage, or the population to be served, or other varying circumstances or requirements, should the particular method of treatment and disposal to be adopted be determined; and II. To make any recommendations which may be deemed desirable with reference to the treatment and disposal of sewage."

Scope of Articles.

In this series of articles the reports (Fourth Report, vol. iv., Parts I. to IV., 1904) to the commission by their specially appointed officers are, as the title indicates, my main consideration. As the investigations, however, on the eight selected typical sewage farms were concluded some time ago I have endeavoured to ascertain what alterations have been made, are in progress, or are proposed. The evidence of the witnesses examined by the commission has been drawn on, as also one or two outside sources. Special note must be made of the fact that the matters dealt with have not yet been reported on by the commissioners themselves. The introductory matter will be found arranged as follows: Historical Summary; Land—Suitable and Unsuitable; Lines of Inquiry; Terms Employed—Change of; Distance from Town—Advantages and Disadvantages; Surplus Area—Value of; Separate (Partially) System—Advantages and Disadvantages; Management; Mechanical

Analysis; Chemical Analysis and Standards; and Bacteriological Analysis and Standards.

Historical Summary.

To trace the historical development of sewage disposal would be an interesting study, but as it is not my immediate subject I will merely indicate the views and practices that have prevailed at various times—the evidence given to the commission, June 22, 1898, by Mr. A. D. Adrian, c.B., Assistant Secretary to the Local Government Board, is replete with information on this topic. From 1842 to 1857 the prompt removal of sewage from the neighbourhood of dwellings was advocated; the discharge of foul matters into rivers was counselled; and the opinion obtained that the irrigation of extensive areas with sewage might be injurious to health. Later (1858-70) irrigation was adopted, and the views were held that the utilisation of sewage on land and the preparation of manure by means of chemical precipitation would both prove to be profitable. The first Sewage Commission reported in 1865, after eight years' labours, that "The right way to dispose of town sewage is to apply it continuously to land, and it is only by such application that the pollution of rivers can be avoided." From 1871 onward intermittent filtration, broad irrigation, and chemical precipitation were in vogue (and are, of course, still in use), and a further commission reporting in 1874 classified them with regard to success in the order given above. Further, the commission appointed to inquire into the discharge of sewage by the Metropolitan Board of Works (Thames) reported in November, 1884, that the liquid separated by chemical precipitation "would not be sufficiently free from noxious matters to allow of its being discharged at the present outfalls as a permanent measure. It would require further purification, and this, according to the present state of knowledge, can only be done

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effectually by its application to land." The present commission say (First Report, § 8, July, 1901): "Since the publication of the last-mentioned report it has been the practice of the Local Government Board to require, save in exceptional cases, that 'any scheme of sewage disposal for which money is to be borrowed with their sanction should provide for the application of the sewage or effluent to an adequate area of suitable land before its discharge into a stream.' There can be no doubt, in our opinion, that the Local Government Board were bound, under the circumstances, to insist upon such a rule."

Lastly, the advent of bacterial processes for the purification of sewage has had far-reaching effects. Not only have many installations been erected throughout the country, but attention has been redirected to land treatment. It is now clear that much of the work performed in the land is due to bacteria, and sewage farms need no longer be conducted by rule-of-thumb methods. Dr. Houston, in the introductory remarks to Part III., draws attention to the fact that the biological qualities of land effluents were unknown, and states that bacteriology has come to be considered an indispensable adjunct to chemistry in the re-investigation of the entire subject. While on this point I would draw attention to the somewhat arbitrary use by the commission of the term "natural" for land treatment, and would ask if it is a *natural* process to apply to the surface of land thousands of gallons of water per acre, so that the many impurities contained therein, and, be it noted, artificially introduced, may be removed. Again, if land treatment be *natural*, why, in the early days of irrigation, was that process deemed a menace to public health?

Land— Suitable and Unsuitable.

The question, "Are some sorts of land unsuitable for the purification of sewage," is answered as follows: "We doubt if any land is entirely useless, but in the case of stiff clay and peat lands the power to purify sewage seems to depend on the depth of the top soil. There are, of course, numerous gradations in the depths of top soil which are met with in nature, and it is not easy to draw the line between lands which contain a sufficient depth to justify their use and lands which do not. We are, however, forced to conclude that peat and stiff clay lands

are generally unsuitable for the purification of sewage, that their use for this purpose is always attended with difficulty, and that where the depth of the top soil is very small, say, 6 in. or less, the area of such lands which would be required for efficient purification would in certain cases be so great as to render land treatment impracticable." (First Report, §15.) "We have considered it desirable to publish, at this stage, the results and information which have been obtained by our own officers in regard to land treatment of sewage and methods of analysis, but we shall defer reporting on these matters until our investigations, which are now in progress, in regard to other methods of sewage treatment, are completed." (Fourth Report, § 117, December, 1903.)

Lines of Inquiry.

The work for the commission was undertaken by the following gentlemen: Dr. Houston (bacteriologist), Dr. McGowan (chemist), and Mr. G. B. Kershaw (engineer). Part I. (Fourth Report, vol. iv.) is a general report (116 pages), Part II., chemical (328 pages), Part III., bacteriological (214 pages), and Part IV., engineering and practical (129 pages). The blue-books are illustrated by maps, plans, diagrams, micro-photographs, &c. The general scope of the inquiry is thus stated in the introduction:—

"Having been instructed by the commission to inquire into the subject of the land treatment of sewage, we proceeded to visit a large number of sewage farms throughout the country. During our inspection of these farms we paid attention to the following points, among others—namely:—

"(I.) The general character of the soil and sub-soil, and whether the original surface soil had been 'lightened' by ashes or other substances, or 'treated' with chalk.

"(II.) Whether or not the land was drained, and, if so, the nature of the drainage arrangements.

"(III.) Whether the land was cropped, and, if so, the nature of the crops.

"(IV.) (a) Whether the whole of the crude sewage (liquid and solid together), or (b) the settled sewage after subsidence in tanks, or (c) the sewage after chemical precipitation and settling, or (d) the effluent from some other artificial process of sewage treatment, was being run on to the land.

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"(V.) Whether surface irrigation or filtration was adopted.

"(VI.) Whether the sewage was a domestic sewage or a mixed sewage. (If the latter, the nature and amount of trade refuse gaining access to the sewers.)

"(VII.) The provisions made for 'treating' storm water on the land, and its bulk in relation to the dry-weather flow of sewage.

"(VIII.) The amount of subsoil water gaining access to the sewerage system, and also the proportion of subsoil water which reached the effluent drains on the sewage farm.

"(IX.) The number of years during which the farm had been in existence.

"(X.) Whether the whole of the soil was really in active operation, or whether any portion of the sewage escaped, in a practically unaltered condition, through cracks or borings into the drains.

"(XI.) Whether the different effluents met and mixed together on the farm and discharged into a common channel or escaped separately into a watercourse.

"(XII.) Whether the effluents were being discharged into a drinking water or into a non-drinking water stream.

"(XIII.) Other points to be considered were: Whether the soil was fresh or showed signs of being overdone; whether the farm was well managed and supervised; whether it was worked mainly with a view to producing a good effluent, or to obtaining a profit from the crops; and whether the sludge was disposed of on the land of the farm, and, if so, how and with what results.

"(XIV.) Further, notes were made with regard to the situation of the farm, the total acreage, the total irrigable area, the average area irrigated at one time, the population draining to the farm, the population per acre irrigated, the number of gallons of sewage per head per day, the dry-weather flow of sewage per twenty-four hours, the number of gallons of sewage treated per acre per twenty-four hours, separate or combined system, cost of treatment, &c.

"The results of our inspection of twenty-nine sewage farms, when considered in relation to the above factors and their manifold and complex combinations, led us to conclude that it would be best

to attack the subject in a broad and general way.* With this object in view, we in the first place limited our observations to the treatment on land either of *domestic sewage* or of sewage containing no excessive amount of trade effluents. Secondly, we differentiated farms according to the nature of their soils. Thirdly, we confined our investigation of the different kinds of soil to seven varieties fairly representative of those found on different sewage farms, and in use, or likely to be used, for the purification of sewage—namely, sand, sand and gravel, light loam, heavy loam, clay, peat, and chalk.

"Lastly, we chose for detailed observation sewage farms representative of the above kinds of soil—namely, Aldershot Camp (sand), Croydon (Beddington) (gravelly loam), Nottingham and Cambridge (light loam), Rugby (High-Level Farm) (heavy loam) [since found to be clay], South Norwood and Leicester (clay), and Altrincham (peaty soil and sand). Luton, a typical instance of a chalk sewage farm, was also kept to some extent under observation. We also obtained some samples from the sewage farms of Worsley (partly peat, partly sand and gravel), Hemsworth (clayey soil), Derby County Asylum (stiff soil overlying red clay), Lindfield (clayey soil), Sandhurst (sandy soil), and Woking (Bagshot sand)." (Part I., pages 5 and 6.)

Terms Employed— "It will be noted that the terms 'filtration' and 'surface
Change of. irrigation' are used in place of

the older terms 'intermittent downward filtration' and 'broad irrigation.' The reasons for so doing may be briefly given as follows: In the first place 'intermittency' is essential whether 'surface irrigation' or 'filtration' is employed, so that if the term 'intermittent' is to be retained, it should be used alike for the two different methods of treatment. But we think it better to employ it in neither case. Further, the term 'downward' would seem to be superfluous in connection with land treatment, and, if stress is laid on this term, an impression is apt to be created that a similar action never takes place where surface irrigation

* "It may be pointed out here that many of the factors about to be dealt with are incapable of being weighed or measured as regards their bearing on the subject as a whole. This being the case, it may be said at the outset that the subsequent interpretation of our facts, in their relation to these variable circumstances, cannot be expected to be other than of the nature of a broad generalisation."

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is employed. Moreover, the term 'surface' irrigation seems to define what takes place better than the expression 'broad' irrigation." (Part I., page 23.)

Distance from Town—
Advantages and Disadvantages. The following passage sums up the position with regard to the proximity to towns of sewage disposal works. The possibility of nuisance is, of course, greater with sewage farms than with bacterial installations, but must in any case be taken into account.

"The advantages on the one hand, and the disadvantages on the other, of having a sewage farm at some considerable distance from the town sewered may be summed up as follows: *Advantages.*—The whole of the sewage may be run on to the land in a disintegrated and partially decomposed condition, without any preliminary treatment. In special cases *rough* screening and settlement of the grit may have to be resorted to. There are sentimental, if not also health, considerations for treating sewage in thinly-populated districts. The land is likely to be cheaper in sparsely-populated districts. There is less likelihood of difficulty in extending the area of the farm to keep pace with a growing population. The longer the outfall sewer, the more likely is the sewage to have a uniform composition and an equable flow. *Disadvantages.*—The solid faecal matter which, taken by itself, has a definite manurial value, and would otherwise be easily manipulated, and the cellulose matters, which have a clogging tendency, pass on to the land with the watery part of the sewage, whereas in the case of *fresh* sewage it is not difficult to screen out much of the solid faecal matter and a certain amount of the paper, and to dispose of it to farmers or to make use of it on the farm itself. If settling tanks and precipitation methods are in operation the sludge is apt to be of small market value and is not readily disposed of. The longer the outfall sewer (1) the greater the initial cost; (2) the greater the cost for repairs; and (3) the larger the amount of subsoil water likely to gain access to the sewer, which, so far as bulk of liquid to be disposed of is concerned, is a positive disadvantage.

"The distance of a sewage farm from the town sewered is usually governed by practical considerations; for example, by the suitability of the soil, the necessity for avoiding pumping, if pos-

sible, &c. The subject is one concerning which it is obviously impossible to pronounce any decided opinion, but in general cases there would, on the whole, seem to be a clear advantage in having a sewage farm at a considerable distance from the town sewered." (Part I., page 8.)

Surplus Area—
Value of. The total acreage must be relatively much greater for surface

irrigation than for deep filtration, and a sewage farm may be so small as to be economically a failure. The extent of the surplus area is a matter of some concern. "It is impossible to lay down any rule as regards what the ratio of the surplus to the total acreage should be. Each case must be judged on its own merits, and in relation to the local conditions. But we are of opinion that, generally speaking, a large surplus acreage is advisable, and it is naturally of great advantage to have this surplus land so circumstanced as to admit of the possibility of its being inexpensively laid out for irrigation purposes, if required." (Part I., page 10.)

Separate (Partially) System—
Advantages and Disadvantages. "Whether it is better to have a separate or a combined sewerage system is a controversial matter, and we content ourselves by briefly referring to some of the advantages and disadvantages of each system. As we have been careful to point out elsewhere, 'street washings' (liquid from the separate system) may be so impure as to render its discharge into rivers undesirable. Since the separate system is seldom carried out in its entirety, we confine our remarks to the partially separate sewerage system. For the sake of simplicity our comments may be confined to a brief consideration of the advantages and disadvantages of the separate system. *Advantages.*—Fluctuations in the sewage flow at the outfall works are reduced during storms. The road detritus is kept out of the sewers. A smaller area of land is required for irrigation purposes at a time when the soil of the sewage farm is already apt to be saturated with rain water. The routine working of the sewage farm is not embarrassed by frequent fluctuations in the volume of sewage, amounting it may be to three or four times the normal. If the sewage is pumped, the extra cost of dealing

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with such increases of flow due to storm water, as are dealt with at the disposal works, is considerably lessened. A saving of cost would also seem to occur in precipitation schemes. In districts where the rainfall is heavy, the rain water is carried rapidly away, and flooding of the low-lying levels of the town is less likely to occur. Sewers even of a large capacity may be quite incapable of dealing satisfactorily with these sudden fluctuations of flow. *Disadvantages.*—The occasional natural flushing out of sewers is lessened. Nevertheless, it is chiefly during dry weather that the sewers require flushing. The dilution of the sewage with rain water is lost to some extent, but against this must be put the increase of total volume of liquid to be dealt with at places where the combined sewerage system is in use, and the fact that 'street washings' *per se* may be of objectionable quality. Instances are not unknown when, through carelessness, the foul-water house drains have been connected up to the pipes of the separate system. The initial cost and maintenance are greater with the separate system, but whether this disadvantage is not more than counterbalanced by, among other things, the larger volume of liquid to be 'treated' at the disposal works, is a difficult point to determine.

"If it were practicable to carry off *all* the storm water rapidly, and, in addition, to treat efficiently the *whole* of the *combined volume* of storm water and sewage at the disposal works, then it is obvious that the combined system would be preferable. But as this would seem to be impracticable, the question largely resolves itself into whether it is better to have (a) a combined system with the storm overflows working at low dilutions, or (b) a separate system with storm overflows coming into operation only very exceptionally—*i.e.*, at higher dilutions. We have not sufficient data to formulate a decided opinion, the more so since adequate records are not available of the average quality of the liquids under (a) and (b) sets of conditions, the results being interpreted in the light of the analyses of 'street washings' liquid *per se*." (Part I., pages 27 and 28.)

Management. "There can be no doubt that even the best of sewage farms with the most suitable soil will, under continued bad management, fail to turn out a satisfactory effluent. The question of whether

or not a particular farm is going to purify the sewage efficiently depends mainly upon the manager, assuming, of course, that the farm has been properly laid out in the first instance, that it has a reasonable volume of sewage to treat, and that the manager has (within certain limits) a free hand in the supervision of sewaging operations. The fact, however, must not be lost sight of that he has often a most difficult post to fill, especially with regard to the crops. The effectual purification of sewage, even with suitable land, can only be accomplished when the farming operations are relegated to the background, and the production of a good effluent considered of primary importance. On the other hand, the manager knows that the crops will probably form an important item in his receipts at the end of the year, and he not unnaturally wishes it to appear that the farm is being worked economically under his supervision. Hence there is a temptation to grow remunerative crops—*e.g.*, cereals—that cannot be sewaged (at all events for the greater part of the year), or to refrain from the further sewaging of crops which may be damaged thereby; meanwhile the land which is under sewage must needs yield, owing to the lack of rest, increasingly unsatisfactory effluents. There may, of course, be some farms where the large area at command in proportion to the volume of sewage to be 'treated' renders the growing of grain crops justifiable, but these are exceptions to the general rule. Land is usually too expensive in the immediate vicinity of towns to allow of this, and the tendency is to take too little rather than too much land for a sewage farm. Speaking generally, large farms are better managed than small ones, this being in great measure due to the fact that the salary attached to the latter does not always offer sufficient inducement to a competent man to undertake the duties. In many instances there are small districts fairly near together, each with its own sewage farm. In such cases a combined scheme would appear to be advantageous; by adopting this course an adequate salary could be paid so as to secure an efficient manager, while the annual cost of treating the sewage would also be lessened. On the other hand, it is possible to have a sewage farm so large as in a sense to be unwieldy. It seems desirable that managers should employ day by day some simple chemical test or tests to enable them to

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follow the results of the working of the farm to the best advantage. It is probable that attention to this point would do much to foster the desire on their part to turn out the best effluent possible, at the expense, if necessary, of the crops. This question is raised quite apart from the larger one of appointing a qualified chemist in connection with all large sewage disposal works. In the case of a new farm it would seem advisable, if practicable, that the prospective manager should be on the spot while the works were being carried out, as he would thereby obtain an insight into details which otherwise it might take him some time to discover (*e.g.*, the nature of the soil and subsoil on different parts of the farm, as disclosed by drainage operations). In connection with this, it may be remarked that the soil and subsoil are rarely uniform in nature throughout a farm, and that therefore the various plots cannot all take the same quantity of sewage. We are unable to recommend the abandonment of farming operations even in connection with filtration sewage farms, because, if intelligently pursued, they make for profit with increased efficiency of the land. The farming operations, however, should always be under the control of the authorities responsible for the proper working of the farm, and the manager should receive written and explicit directions to regard the crops as of secondary importance to the uniform and satisfactory purification of the sewage." (Part I., pages 115 and 116.)

Mechanical Analysis.

"As was recognised thirty years ago by the Rivers Pollution Commission, the purification of sewage by filtration through a soil depends largely upon the physical structure of the latter, as well as upon its depth. It was therefore thought advisable to make a careful mechanical analysis of the soils of those sewage farms which have been under prolonged observation. In the case of stiff clay soils, through which little filtration can take place, a mechanical analysis has, of course, less value than in the case of porous soils. Some of the main points in connection with the filtration of water through soil are admirably summarised by Whitney in the U.S. Weather Bureau Bulletin No. 4, as follows: 'The circulation of water in the soil is due to gravity, or the weight of water, acting with a constant force to pull the water

downward, and also to surface tension, or the contracting power of the free surface of water (water-air surface), which tends to move the water either up or down, or in any direction, according to circumstances. There is a large amount of space between the grains in all soils in which water may be held, ranging from about 30 per cent. in light sandy lands to 65 or 70 per cent. in stiff clay soils. The relative rate of movement of water through a given depth of soil will depend upon how much space there is in the soil, upon how much this space is divided up—*i.e.*, upon how many grains (particles) there are per unit volume of soil, upon the arrangement of the grains of sand and clay, and upon how this skeleton structure is filled in and modified with organic matter. It also appears that the ordinary manures and fertilisers change this surface tension or pulling power of water; that they also change the arrangement of the grains, and consequently the texture or structure of the soil may be changed and the relation of the soil to water, through the effect of the ordinary manures and fertilisers in causing flocculation or the reverse.' The volume occupied by any given weight of a soil is only partly filled up by solid particles, there being small air spaces between these. Owing, however, to the vastly greater number of particles in heavy soils, their individual air spaces are very much smaller than the individual air spaces of a sandy or a gravelly soil. Filtration therefore proceeds with much greater difficulty in the case of clay, owing to increased friction. It can, of course, be seen at a glance that, in a given volume of a coarse gravelly or sandy soil, there must be a smaller number of particles than in an equal volume of a light loam, and similarly it is evident that a light loam contains fewer particles than a heavy loam or a clay. Experience has proved that a light loam gives better results, as regards sewage purification, than either sand on the one hand or heavy soil on the other, but it was with the hope of finding a more or less definite relation between the number and size of the particles in a soil and the purifying powers of that soil that this investigation was undertaken; or, to put it differently, one object of this investigation was to attempt to find an approximate limit—as regards efficient filtration of sewage—for the number of particles permissible in unit volume of a soil. The

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main object was to see whether the mechanical analysis of a soil and subsoil would afford data of a sufficiently definite character to allow of an approximate calculation being made as to the amount of sewage which that soil and subsoil would purify." (Part II., page 275.)

Chemical Analysis and Standards.

"In every case, excepting where it is otherwise specified, the *whole* sample of a sewage or effluent—*i.e.*, liquid and solid together—has been taken for analysis. In the case of *sewages* it is this muddy liquid which the land has to treat, and in the case of *effluents* it is the resulting mixture (supposing suspended solids are present) which runs into brook or river. The point was carefully considered by the commission at the time when systematic chemical work was begun for them, and the conclusion was arrived at that it represented better the actual state of affairs to analyse an effluent as it was actually discharged than to allow it to settle and then analyse the clear liquid." (Part II., page 2.) "For the convenience of those who are accustomed to gauge purification by the percentage diminution of albuminoid nitrogen and 'oxygen absorbed' from permanganate, this calculation is given for each set of final and general effluents. But it must not be forgotten that the organic matter of a well-purified effluent is quite different as regards fermentability from the organic matter of a diluted sewage showing the same figure for albuminoid nitrogen, and that therefore this calculation—while convenient—is purely empirical and unscientific. It is further to be borne in mind that in summer, at all events, the purification of sewage by land is really better than it appears to be on the basis of such a calculation, because of the concentration of the liquid due to absorption by plants and to evaporation." (Part II., page 4.)

"With respect to effluents, it will be observed that neither in this nor in the Chemical Report has any fixed chemical standard for effluents been specified. . . . At the same time it should be said here that in endeavouring to arrive at the quality of any particular effluent, or of the effluents generally, from any one farm, the following points, among others, have been borne in mind:—

1. The smell of the effluent and its general appearance with regard to colour, solids in suspension, &c.

2. How the effluent would be judged (speaking approximately) by the Mersey and Irwell provisional standard* as regards albuminoid nitrogen and 'oxygen absorbed' from permanganate (but allowing to some extent for the 'oxygen absorbed' being determined from strong permanganate at 80 deg. Fahr., and not from weak permanganate at 60 deg. Fahr.).
3. Whether or not it withstood the incubator test.
4. The amount of dissolved oxygen present at the time of analysis† and the comparison of this with the quantity present when the sample was drawn, having regard here also as to whether a surface irrigation or a filtration effluent was in question; further, whether any oxygen remained after incubation either at atmospheric temperature or a temperature of 26·7 deg. C. (80 deg. Fahr.).
5. The amount of nitrate present, and how far that nitrate was reduced upon incubation.
6. The approximate ratio of oxidised (*i.e.*, nitric + nitrous) nitrogen to the albuminoid, and to the total organic nitrogen, and also to the total unoxidised nitrogen." (Part I., page 46.)

Bacteriological Analysis and Standards.

"In the case of *drinking-water streams*, the standard which I advocate is partial sterilisation, the destruction of *B. coli* to the extent of securing its absence in 1 c.c. of the effluent being taken as satisfying such standard. Complete sterilisation of sewage effluents would not seem to be a practical measure, otherwise this higher standard would be recommended.

"As regards *non-drinking-water streams*, the standards which I recommend are *provisional and*

* "The well-known Mersey and Irwell *provisional* standard, using weak permanganate at 60 deg. Fahr., is 1·43 parts 'oxygen absorbed' per 100,000 . . . the equivalent figure for this, when using strong permanganate at 80 deg. Fahr., would be about 2·4, or, at all events, rather over 2 parts per 100,000." (Part II., page 4, footnote.) "The standard for albuminoid nitrogen is '12 part per 100,000.'" (Part I., page 62.)

† "A fully aerated sample would contain roughly about 7 cubic centimetres of oxygen per litre—*i.e.*, 7 volumes of oxygen per 1,000 volumes of water."

Introductory.

for working purposes only. For the chief tests employed they are as follows:—

Total number of bacteria	{	Gelatine at 20 deg. C.	{ less than 100,000 per c.c.
		Agar at 37 deg. C.	{ less than 10,000 per c.c.
B. coli			{ less than 1,000 per c.c.
* B. enteriditis sporogenes test and 'Gas' test (twenty-four hours at 20 deg. C.)			{ Negative results with 0.1 c.c.
Indol test (five days at 37 deg. C.)	{	Neutral-red broth test (two days at 37 deg. C.)	Negative result with 0.001 c.c.
Bile-salt broth test (two days at 37 deg. C.)			
Litmus milk (modified) test (two days at 37 deg. C.)			

“These are primary standards; my secondary standards are arrived at by rendering the primary

* “It will be seen from the results detailed in Appendix VII. that, in connection with the routine use of the B. enteriditis sporogenes test, the habitual inoculation of rodents is neither necessary nor wholly justifiable.”

standards ten times more lenient.” (Part III., pages 12 and 13.)

Dr. Houston, in the introduction to Part III. (Bacteriological Report), draws special attention to the necessity for distinguishing between effluents that are to be discharged into drinking-water and into non-drinking-water streams. In this connection the protection of shell-fish and watercress must also be borne in mind. It may be of interest to state here that during convalescence typhoid bacilli pass out of the body by way of the kidney and urine in enormous numbers—up to 6,000 million per cubic centimetre. (Dr. Horton Smith, Gulstonian lectures before the Royal College of Physicians, 1900; quoted by Prof. Klein on page 10; Experiments and observations on the vitality of the bacillus of typhoid fever and of sewage microbes in oysters and other shell-fish—investigations on behalf of the Worshipful Company of Fishmongers—May, 1905.)

PRELIMINARY.

In the first place I propose to deal *seriatim* with the eight sewage farms—Aldershot Camp, Altrincham, Cambridge, Croydon (Beddington), Leicester, Nottingham, Rugby (High Level), and South Norwood—that were under detailed investigation by the officers of the commission. Where possible an account of each farm up to 1900 to 1901 will be given, and this will be followed by a review of the information contained in the blue-books. The chief points will be taken in order: (1) The composition of the sewage and the preparation thereof before passing on to the land; (2) the nature of the soil and subsoil; (3) figures relating to acreage, population, &c.; (4) method of treatment of sewage and cropping of land; and (5) analysis—*i.e.*, quality of effluent as compared with sewage and with stream. It is not my intention to refer to the financial side of the question; firstly, because most of the farms were in operation before the introduction of bacterial methods as such for the purification of sewage, and therefore land treatment was practically inevitable; and, secondly, on account of the great diversity which exists with regard to the many points that would have to be considered, and of which no comparison is really possible. The works that have been constructed since 1900 to 1901 will be noticed, and the schemes that are now in hand will receive attention. Particulars of the eight farms are briefly summarised in a table immediately following the last detailed description. The experiments at Croydon, Leicester and South Norwood, and the treatment of “new land” at Aldershot Camp are referred to. Details (which I have tabulated) respecting other places visited will be found, and also notes from the various reports thereon.

Further, some remarks with regard to Andover (Dr. Poore's system), buried sludge (Cambridge),

value of effluent, storm water, artificial storm waters, surface street washings, and subsoil water are included.

A word or two of explanation is necessary with regard to the points selected and the tables copied or prepared. The state of the sewage on arrival at the outfall depends largely on the many factors hereafter detailed, and in considering the degree of purification effected, the composition of the sewage, the whole design of the sewerage system, and the nature of the preliminary treatment, must be carefully borne in mind. The soil and subsoil tables are reduced from those given in the blue-book. In acreage, population, &c., it should be understood that the number of persons and the volume dealt with per irrigable acre are stated for purposes of comparison only. The analytical tables give the more important figures for the sewage effluent and stream together—this should facilitate comparison. “As far as possible, different times of year were chosen for the visits to each of the farms selected for observation, with a view to (1) ascertaining, if possible, to what degree the effluents were affected by seasonal variations in temperature, rainfall, &c., and (2) obtaining a fair idea of the working of the farm throughout the year. It is perhaps hardly necessary to add that a considerable element of uncertainty existed as to the prospective meteorological conditions. On more than one occasion a spell of cold weather occurring in the warmer months of the year, and conversely a period of warm weather during the cold season, upset our anticipations to a considerable extent.” (Part I., page 37.) That the influence of the air temperature on the temperature of the effluent resulting from surface irrigation is very marked is shown by the figures of air, sewage and effluent temperature in the case of Croydon and South Norwood; the temperature of the effluents

Preliminary.

varied *pari passu* with the changes in atmospheric temperature.

With regard to the hourly sewage samples, I do not quite understand why, in endeavouring to estimate the strength of the sewage, such an incorrect method of sampling was adopted. It is a matter of common knowledge that the sewage varies very considerably during the twenty-four hours, both in strength and in volume, and I am not aware of any insuperable difficulties in the way of obtaining samples which would approximate very closely indeed to the real average strength of the sewage. A comparison of the effluents and streams is given, including a short table (dissolved oxygen). In each case the effluent flows into a non-drinking-water stream. The view prevails that fish are more affected by the absence of oxygen than by the presence of domestic sewage, either fresh or undergoing decomposition. The minimum amount of dissolved oxygen needed to support fish-life is about 1 cub. in. per gallon (equal to, say, 3·6 c.c. per litre), and it must be clear that an effluent should not in this respect foul the river into which it flows.

QUANTITY OF OXYGEN DISSOLVED BY WATER AT VARIOUS TEMPERATURES. Corrected to 0 deg. C. at 760 mm. pressure.		
Temp. Fahr.	Temp. C.	Cubic inches of Oxygen per gallon.
41	5·00	2·40
50	10·00	2·15
59	15·00	1·93
68	20·00	1·73
[To convert cub. inches per gallon into c.c.'s. per litre $\times 3\cdot6$.]		

The above Table is extracted from Table lxxix, in "The Purification of Sewage and Water," by W. J. Dibdin, F.I.O., F.C.S., third edition, 1903.

I have visited all the farms dealt with in detail, Leicester excepted, and have to acknowledge the courtesy that has been extended to me by the respective engineers and bailiffs. I am indebted to the engineer of the Corporation of Leicester for the report giving full particulars of the work now in hand.

ALDERSHOT CAMP.

HISTORY.

The extreme natural poverty of the soil (sand—consisting of almost pure silica) does not seem to have been a hindrance to the efficiency of the process of cleansing by irrigation.

The population is about 7,000, and some 700 tons per day of sewage are treated. The area of the farm is 80 acres in all. A previous attempt to deal with the sewage by subsidence and filtration tanks had been a complete failure.—Rivers Pollution Commission, First Report, vol. i., pages 77 and 78 (1870).

The following notes and extract are taken from the book "Natural and Artificial Sewage Treatment," by Lieut.-Col. Alfred S. Jones, v.c., ASSOC.M.INST.C.E., &c., and Mr. H. Alfred Roechling, M.INST.C.E., &c., published in 1902. Col. Jones, who, by the way, is now a member of the institution, is the author of that part of the work appertaining to Aldershot Camp.

Col. Ewart devised the separate system as used, and Mr. James Blackburn was employed by the War Office to deal with the camp sewage on about 100 acres of rough heather-covered land. In 1879 the farm was, after fourteen years' work, in very good order, and a wooden shed had been built and sub-let to a man who bought the ryegrass for some fifty cows. Mr. Blackburn was in treaty with the War Office for new terms, but the sub-tenant made a tempting offer and secured a fourteen years' lease. In May, 1895, Col. Jones was called in to inspect and report. "I found the whole farm in a deplorable condition of neglected nuisance, stagnant lakes of sewage retained here and there by banks of earth, buildings and fences in decay, and the greater part of the camp sewage passing, by pipes laid by its tenant, under a road which forms the lower boundary of War Department land, to some rough meadows held by their tenant from civilian owners for the purpose of saving him the trouble of spreading the sewage over the sloping surface of the War

Department Farm—work which required the use of a land surveyor's level and staff. In the ditches of these flat meadows the sewage could go through the septic process to its fullest extent, as the level of the river Blackwater kept them nearly full at all times, and the supernatant liquid could spread over the coarse herbage of these meadows only in winter floods, with the result of heavy crops of hay, and sewage disposal conveniently out of sight and outside War Office jurisdiction, when a Royal Engineer officer might come to inspect the Camp Farm from time to time" (pages 10 and 11). Since then the farm has been managed by Col. Jones, and the result has been most satisfactory.

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Separate.—The sewerage of
The Sewage. Aldershot Camp is so arranged as to give, practically speaking, completely separate systems for sewage and for rain water. This is an important point to note because as a rule the so-called separate system includes a considerable proportion of the rainfall in the foul-water sewers. The sewage is entirely *Domestic*, and is unusually strong. But little *Sub-soil Water* finds its way into the sewers, and when on one occasion .75 in. of rain fell in four hours the flow per twenty-four hours was only increased to the extent of about 50 per cent. The *Dry-weather Flow* is 1,000,000 gallons per diem, and the extreme *Storm Flow* may be taken as 1,500,000 gallons. *Water Supply.*—The water consumption per head is large, and probably averages in the neighbourhood of 43 gallons. The *Rainfall* is about 22 in. per annum. The *Stay in Sewers* is under one hour each for the Marlborough and Stanhope Lines and about two and a half hours for the Wellington Lines, the *Distances* being respectively $\frac{3}{4}$ mile in the first two cases and $1\frac{1}{2}$ miles in the last case. *Sewer Capacity.*—The Stanhope Lines sewer is a 15-in. pipe, with a gradient of

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1 in 400, and a capacity, when running full, of 210 c.f.m.;* the Wellington Lines sewer is a 12-in. pipe, and passes under the Basingstoke Canal by an inverted syphon just before entering the farm; and the Marlborough Lines sewers are 12 in. and 15 in., with a combined capacity when running full of 246·6 c.f.m. There is one *Detritus Chamber* on the Stanhope Lines sewer, where a good deal of sand collects—it is cleaned out every six weeks or so, from 5 to 8 tons being removed. *Screens*.—As the sewage is very fresh the paper and fæces are easily removed. The screens are made of $\frac{1}{2}$ -in. galvanised iron bars, set $\frac{1}{2}$ in. to $\frac{3}{4}$ in. apart, at an angle of 45° to the flow—they are cleaned every hour. *Settling Tanks*.—The Stanhope tanks are in duplicate, each 64 ft. by 12 ft., with an average depth of 1 ft. 6 in. Each is used in turn for a period of two to three weeks, and the sludge is run into the sludge bed. The tank is then brushed perfectly clean. The Wellington Lines tanks are 70 ft. by 10 ft. by 1 ft. 8 in., and the Marlborough Lines tanks 80 ft. by 12 ft. by 3 ft., and they are worked in the same way. *Stay in Tanks*.—The capacity of the Stanhope and Wellington tanks is about 6,500 to 7,000 gallons each—this, with a flow of one-third of a million gallons for each set, gives a stay in the tanks of about thirty minutes. A single new Marlborough tank holds 18,000 gallons, and the sewage takes approximately one hour

end of this section, compared with those of the effluent and of the stream.

Soil and Subsoil.

Originally the *Soil* was an almost pure sand—there is now a surface soil of 4 in. to 12 in., produced by sewaging and by ploughing in sludge, incorporated with farmyard manure. With the exception of one field 20 tons of chalk have been applied per acre as a dressing. The *Subsoil* consists of a little gravel in parts, but is mostly of very fine sand, with a tendency to pug.* An impervious pan,† at a depth of 2 ft. to 4 ft., is noticeable, though it has now in great measure been broken up by under-draining. *Under-drainage*.—The land has a slight slope eastwards to the river Blackwater, but there is not sufficient fall to create a good draw in the drains. The 3-in. agricultural pipes are laid at an average depth of 3 ft. 3 in., and generally about 12 yds. apart. They communicate with larger pipes (up to 15 in.), which discharge into an effluent chamber. *Subsoil Water and Floods*.—In winter during rainfall there is some subsoil water, but as a rule when the tank effluent is taken off a plot the under-drains run dry. The land is not subject to flooding.

The *Mechanical Analysis* shows the following percentage composition of the ignited soil and subsoil:—

MECHANICAL ANALYSIS.							Soil.	Subsoil.
Fine gravel (above 2 mm.) — medium sand (above 0·25 mm.)	...	...	...	...	...	...	8·36	4·09
Sand (0·25 — 0·05 mm.) — silt (0·05 — 0·01 mm.)	...	...	...	...	...	...	84·69	85·71
Dust (0·01 — settling from water within twenty-four hours) — clay (still finer — precipitated by dilute nitric acid)	...	...	...	...	...	...	2·29	7·41
Loss on ignition (separate determination)	...	...	...	...	...	...	3·60	1·80
							98·94	99·01

and twenty minutes in its passage through it. The *Screenings* (about two wheelbarrow loads per tank per day) and the *Sludge* (about 20 to 30 tons, wet, at each emptying of the tanks combined) are deposited together in beds formed with a fender of long stable manure, and eventually are applied to the farm. The *Analyses*, both chemical and bacteriological, of the sewage will be found at the

* Cubic feet per minute.

The approximate number of particles in 1 gramme was, for soil, 154,373,990; subsoil, 1,142,111,850; and in 1 c.c., for soil, 226,466,640; subsoil, 1,677,742,900.

The *Lime* (parts per 100,000) dissolved by water in twenty-four hours is, for soil, 0·004; subsoil,

* By pug is meant a tightening of the surface sand and consequent obstruction to filtration.

† Sand cemented together with iron oxide.

Aldershot Camp.

0.005; and dissolved by water saturated with carbonic acid in forty-eight hours, for soil, 0.030; subsoil, 0.018.

The total area of the farm is 138.5 acres, and of this 120.5 acres are available for sewage treatment. The available area under irrigation at

regard to the treatment of "new land" will appear hereafter. *Cropping.*—The main crop is Italian rye-grass, cabbages and mangold wurzels are also grown, there are 2 roods of osiers and some rhubarb beds. The produce of the farm is largely used to feed milch kine, of which some forty-eight are generally kept—they do not leave the stalls until they are "out-of-profit."

DATES OF VISITS, MEAN TEMPERATURES, RAINFALL, &c.

Dates of Visits.	Mean Temperatures (deg. Fahr.).			Mean daily Rainfall (inches).	Remarks.
	Air.	Sewage.	Effluents.		
1900. March 12—April 2	39	45	44	.05	.30 rainfall on four days (average). Snow on two days.
May 28—June 7	56	59	54	.02	.09 rainfall on May 31st. Land just brought into use specially under observation.
1901. April 1	—	49	42	—	—
June 19—July 24	63	67	58	.06	.80 rainfall on June 30th and .64 on July 2nd.
October 14—18	—	55	50	.266	.65 rainfall on October 18th and .55 on October 16th.
1902. January 28—30	—	—	37	.00	Twenty-four hours' sewage and effluent samples taken.

one time is 40 acres; the population served is 20,000, which works out at 166 persons per irrigable acre, or 498 persons per acre for the average area irrigated. The normal dry-weather flow is 50 gallons per head per diem. The amount treated per acre for twenty-four hours at the normal rate of flow is 24,900 gallons on the average area irrigated, equal to 8,300 gallons on the whole irrigable area.

Treatment and Cropping.

Treatment.—The sewage flows in main carriers (pipe, half-pipe, and earthen plough-formed) along the highest sides of the plots, and is distributed by contour grips or channels. These are 50 ft. to 60 ft. apart, are diverted sufficiently from the true contour line to give the required fall and run out before the further side of the plot is reached. It should be noted that the men under Col. Jones's supervision have been, and are, from time to time employed in improving the surface levels, the object in view being to pass the sewage in a thin stream over the land. Some notes with

Analyses— Sewage, Effluent and Stream.

The sewage is screened while very fresh, and some settlement occurs in the tanks. Considerable evaporation takes place, especially in summer. The chief *Chemical* results are given on following page.

"All the effluents were more or less yellow or brown in colour (but those tested for this point were colourless or light yellow when filtered), and they contained *very decided* amounts of red-brown flocculent suspended solids—*i.e.*, fragments of weed coated with red oxide of iron, washed from the drains. These solids are, however, extremely light. . . . Excepting No. 56 (a bad sample, drawn in part from land which was undrained and not levelled) and No. 90 [not analysed], both of which had a putrefactive smell, and No. 247, which had a suspicious smell, but was nevertheless a good effluent, all the samples had either a clean earthy or a fishy-earthly smell when they came to be analysed; a few of them, however, were noted as having more or less of a sewage smell when drawn. One or two had an alkaline reaction, but the

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general reaction was acid from dissolved carbonic acid derived from the oxidation of the carbonaceous matter of the sewage; they all became alkaline upon boiling. I have noted with regard to No. 89 (and this is no doubt true of the others also) that the colour of the liquid was in part due to dissolved organic matter. These effluents contained only a moderate amount of lime [the proportion of lime in the soil was very small as compared with that found at the other farms] in solution, but much sulphate." (Part II., page 13.) "The Aldershot Camp Farm treats on a sandy soil and subsoil a medium volume of a strong sewage per acre of irrigable area, and at the same time a large quantity of organic matter. The effluents produced

percolation through a depth of 3 ft. . . . The rate of filtration through such a very fine sandy subsoil must be rather slow." (Part II., page 18).

The *Bacteriological* figures may be summarised as on following page.

"The results, as a whole, do not suggest the impracticability of land similar to that at Aldershot Camp sewage farm being worked so as uniformly to produce an effluent which would pass the provisional standards that have been tentatively suggested. In this connection it is noteworthy that as regards most, at all events, of the tests employed, a number of the effluents not only 'passed,' but easily 'passed,' the respective standards for non-drinking-water streams. Moreover, a ma-

CHEMICAL ANALYSES (PARTS PER 100,000 BY WEIGHT).			
—	Sewage.*	Effluent.† (16-18 samples.)	Stream. (3 samples.)
Total nitrogen	16.53	6.0	3.02
Ammoniacal nitrogen	11.19	1.85	2.63
Total organic nitrogen	5.28	—	—
Albuminoid nitrogen	2.48	0.26 { 91.4 per cent purification (average) }	0.18
Oxygen absorbed 4 hours at 80 deg. Fahr. ...	24.65	2.72 { 88.85 per cent purification (average) }	1.72
Nitric and nitrous nitrogen	—	3.21	0.18
Chlorine (in water supply say 1.5 and in subsoil water 1.2)	12.28	10.93 (?)	7.69
Incubator test as judged by smell	—	{ 89 per cent passed (18 samples) }	{ 2 sweet 1 putrid }
Solids in suspension (hourly samples only) ...	36.6	—	—

* Approximate averages of three sets of samples drawn in equal quantities per hour for twenty-four hours and of nine chance samples.
† The figures are probably a trifle too high, as some of the samples included a little effluent water from the "new land."

may be summed up as being highly nitrated, and, although some or most of them still contained appreciable amounts of organic matter, not very much of that was of a fermentable character under laboratory conditions of experiment; further, the nitrate present was much more than sufficient to keep them sweet. They had in them more flocculent suspended solids—washed out of the drain pipes—than was desirable. Would it be possible to settle these out or to screen them before the effluent passes into the brook? Although, therefore, these effluents cannot be reckoned among effluents of the highest class, they are no doubt as good as can be obtained from a sandy soil, which has to treat a fairly large volume of strong sewage by one

majority, not a minority, of the effluents either 'passed' or came within measurable distance of 'passing' the standards set up for the various tests. But obviously it would be necessary to alter, in some way or the other, the existing methods of working the farm, or else to acquire an additional area of land, in order to obtain uniformly satisfactory results. From Mr. Kershaw's notes it appears that the farm is well managed. It follows from this that either an additional area of land would be required to produce a uniformly satisfactory effluent, or else that the standards suggested require modification. As regards the latter point, it is desirable to point out in as emphatic a manner as possible that the suggested standards

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are merely provisional for working and comparative purposes, and need not necessarily be adopted, as they stand, without modification. . . . It is not improbable that the strength of the sewage, the length of time the farm has been in operation, the fact that the sludge is ploughed into the land, and the hardy nature of spores as compared with bacilli, may account for the results being seemingly less satisfactory with the *B. enteriditis sporogenes* test than with the other tests employed in the investigation. It is, perhaps, hardly necessary to add that, considered from the bacteriological point of view, none of the samples of effluent were in a fit state to be turned into a drinking water stream." (Part III., pages 25 and 26.).

The normal volume of the river is increased considerably by heavy rainfall. This small river was not in a satisfactory state at the times when the observations were made, more especially during summer, but this was due to polluting matter entering it above the farm. The Aldershot Camp Farm effluent from the old land must have exercised an oxidising effect on the organic matter already present in the water. At the same time attention should again be called to the rather considerable bulk of fine flocculent weed (from the drain pipes) which is carried into the stream along with the effluent, and also to the high manurial value of the effluent itself. Not only is there a great loss of nitrate and other manurial constitu-

BACTERIOLOGICAL ANALYSES (TOTAL NUMBER OF BACTERIA PER C.C.).			
	Sewage. (8 samples.)	Effluent.* (9-28 samples.)	Stream. (1 sample.)
(1) Gelatine at 20 deg. C.	30,460,000	183,266 { 99 per cent reduction }	8,200
(2) Agar at 37 deg. C.	4,556,000	37,308 { 99 per cent reduction }	500
(3) <i>B. coli</i> or closely allied forms (say at least)...	100,000	1,359 { varied from at least 1 not 10 to at least 10,000 }	At least 10
(4) <i>B. enteriditis sporogenes</i> (spores—say at least)	1,900	38 { varied from none in $\frac{1}{10}$ c.c. to at least 100, but less than 1,000 }	At least 10
* Taking the above tests in order, the following passed the provisional standards (non-drinking water streams): (1) 8 out of 12, (2) 11 out of 18, (3) 6 out of 9, and (4) 4 out of 28 effluents. The tests are: (1) less than 100,000, (2) less than 10,000, (3) less than 1,000, and (4) less than 10. The figures are probably a trifle too high, as some of the samples included a little effluent water from the "new land."			

Effluent and Stream Compared. The flow of effluent varies considerably according to the temperature. In very hot weather the effluent is often only one-half of its normal quantity, the remainder being absorbed or evaporated. The normal dry-weather flow is about two-thirds of the ordinary dry-weather flow of sewage, or about 600,000 to 700,000 gallons per twenty-four hours, which shows 1 gallon out of 3 gallons as being absorbed or evaporated; the quality of the effluent does not appear to vary much either in summer or winter. The river Blackwater, into which the effluent finally passes, is a small, muddy, sluggish stream. The ratio of effluent to river water is about 1 to 6 approximately.

ents here, but the effluent must tend to choke the stream indirectly by encouraging vegetable growth in it.

In only six of the seventeen samples was there more than 2 c.c. per litre of dissolved oxygen left when the effluent came to be analysed; in four the oxygen varied from 1 c.c. to 2 c.c.; and in the remaining seven it was either *nil* or less than 1 c.c. Being percolation effluents, these were probably not fully aerated when drawn, and, further, the copper chloride oxygen process would give too low readings with such coloured effluents (the first seven were boiled out). But even allowing for this, and for the fact of the rate of absorption of dissolved oxygen being largely a question of tem-



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perature, these figures indicate that there was still a little fermentable organic matter left in some of the effluents. In the summer samples of water from the stream the dissolved oxygen had gone down to zero, or nearly zero, in every case when the analysis came to be made; this is, of course, very unsatisfactory.

was treating a *large volume* of sewage, either per acre of the 'working' daily irrigable area, or per acre of the total irrigable area; but it was treating, both actually and relatively, a *large quantity* of organic matter. Moreover, the soil and subsoil (coarse sand over very fine sand) are not of the best kind for purifying a large volume of sewage,

DISSOLVED OXYGEN (PARTS PER 1,000 = C.C'S. PER LITRE).					
			Boiled out.	Cuprous Chloride at time of	
				Drawing.	Analysis.
Effluent	...	...	0.12 — 5.30 average 2.54	— — average —	0.0 — 3.2 average 1.1
Stream	...	...	— — — 6.89	— — 5.0	0.0 — 1.1 „ 0.55
Mixture	...	...	6.51 — 6.77 „ 6.64	— — 3.0	— — 0.0

Nuisance and Difficulties. There is no objectionable smell noticeable on the farm in connection with the distribution of the sewage, except in removing and carting the sludge, but this is in no degree worse than that which would occur in leading manure on any ordinary farm. One of the principal difficulties formally experienced in the working of the farm was that of obtaining farm labourers in the immediate vicinity of the Camp. There was also a lack of suitably built cottages, now provided close to the farm. Another difficulty was the delay experienced in obtaining the carrying out of necessary improvements. The number of men employed on the farm varies considerably, but is usually from twenty to thirty, working under the direction of the farm bailiff, superintended by Col. Jones.

Conclusions. "The sewage (purely domestic) is strong. It cannot be said that for a filtration farm Aldershot Camp

and the average filtration depth down to the drains is only about 3 ft. . . . On the whole we consider that 25,000 gallons per acre for twenty-four hours (8,300 gallons per acre on the total irrigable area per twenty-four hours) is too large a volume of a strong sewage to be treated by screening, settling, and filtration, through about 3 ft. of sand of the above nature, if completely and uniformly satisfactory effluents are to be expected, but not too large a volume of sewage per acre to yield effluents showing a high percentage (possibly even a sufficient relative degree) of purification." (Part I., page 81.)

LATER WORK.

The area of the farm, the method of treatment, &c., remain unaltered. A footnote to page 10 of Part II. runs: "Since then we understand that the water supply has been reduced to 25 gallons per head."

ALTRINCHAM.

HISTORY.

No reference is made in any text-book or report, so far as I am aware, to this farm. It was started about 1870, and in all probability the population served gradually increased and thus threw a growing burden on a small area of land.

REPORTS TO THE ROYAL COMMISSION.

Conservancy.—It is stated in the Engineering Report (Part IV., page 24) that "water-closets are in use over the greater part of the town; there are, however, a few privies, the contents of which are not dealt with at the sewage farm." I am informed that there are 2,325 privies, 1,440 wet ashpits, 1,221 dry ashpits and 1,464 water-closets, so that it would appear that the sewage does not contain all the human excrement. The sewerage system is on the *Combined* method, all street, roof, and back-yard water being admitted to the sewers. During rainfall large fluctuations occur in the sewage flow, and very frequently the outfall sewer is too small therefor. The roads are principally macadam. There is practically no manufacturing effluent; the sewage is therefore *Domestic* in character. *Subsoil Water.*—The population per acre of drainage area is small—viz., thirty-six—and consequently the subsoil leakage to the sewers per head is proportionately more than would be the case in a thickly populated district; further, two small ditches run into the main sewer where it passes by a syphon under the Bridgwater Canal. The average *Dry-weather Flow* is 800,000 gallons per diem. The *Storm Flow* must approximate to that theoretically possible—namely, 1,800,000 gallons per twenty-four hours. The *Water Supply* is derived from the Wood-Head source. The *Rainfall* is 37 in. per annum, and the *Drainage Area* is about 500 acres. *Flushing.*—With the exception of the main gravitation outfall sewer the general lines of sewers have fairly good falls throughout. They are not

flushed at any time. *Stay in Sewers.*—The average time taken by the sewage to reach the farm is about three and a half hours, the *Distance* being about 2 miles. *Sewer Capacity.*—A 21-in. sewer is laid to the farm at a gradient of about 1 in 2,174, having a theoretical capacity, running full, of about 1,800,000 gallons per day. The outfall sewer being at such a flat gradient has not a self-cleansing velocity, and has a tendency to silt up rapidly in consequence. *Storm Overflows.*—Near West Temperley station two ovoid brick sewers discharge into a chamber provided with a storm overflow sill and iron flap valve opened during storms by the head of sewage and storm water. It discharges by a 3-ft. 9-in. circular brick culvert into an adjoining stream, which eventually flows into the brook receiving the farm effluent. At present this main storm overflow works at less than one of storm water to one of sewage, or less than twice the dry-weather flow. There are, in addition, two other local storm overflows. It is from this chamber that the outfall sewer to the farm starts. *Detritus Chamber.*—About 150 yds. from the storm overflow chamber the sewage passes through a small catchpit 20 ft. by 2 ft. by 2 ft. deep, and any accumulation of silt or sand (such as that caused by laying a new sewer) is extracted here when necessary. There is one *Settling Tank*, 70 ft. by 6 ft. by 3 ft. 9 in. average depth, formed with a circular bottom. Owing to the small capacity of the tank but little appreciable settlement is effected. The *Stay in Tank* is very short, being under twenty minutes. The *Sludge* is drawn off about once a week by means of a chain pump into an adjoining sludge bay 68 ft. by 18 ft. by 2 ft. 6 in. When it has dried sufficiently it is mixed with farmyard manure and ploughed or dug into the land where required. The *Analyses*, both chemical and bacteriological, of the sewage will be found at the end of this section compared with those of the effluent and of the stream.

Land Treatment of Sewage.

Soil and Subsoil.

The *Soil* varies in places, the surface soil consisting of 8 in. to 10 in. of black porous soil mixed with and lying upon a layer of decomposed peat 4 in. to 7 in. deep. The *Subsoil* is fine, white sand and gravel. About one-half of the farm was formerly pure bog-land (Carrington Moss), the remaining half or southern portion of the farm is of a sandier nature. The actual peat land is not irrigated. There is a large quantity of iron in the soil, and a pan of some 3 in. to 6 in. in thickness occurs in places. *Under-drainage*.—The irrigated area is under-drained, 4 yds. to 5 yds. apart, with ordinary 4-in. pipes about 3 ft. 6 in. to 4 ft. deep, laid parallel and joining 9-in. stoneware socketted master-drains, which are connected up to brick effluent manholes. *Subsoil Water and Floods*.—There appears to be a little subsoil water present in the drains in wet weather. The land is not liable to floods.

The *Mechanical Analysis* shows the following percentage composition of the ignited soil. The subsoil was not analysed.

per acre for twenty-four hours at the normal rate of flow is 46,000 gallons on the average area irrigated, equal to 23,000 gallons on the whole irrigable area.

Treatment and Cropping.

Treatment.—From the settling tank the sewage passes along a main carrier; closed pipe carriers are also used. The bricks in the sides of the main carrier have perished badly with the frost, and grease, &c., accumulates against the sides and hinders the cleansing of the carriers. From the main carriers the sewage either flows directly on to the land or first into spade-formed subsidiary carriers, as the case may be. Owing to the insufficient capacity of the settling tank, sewage is usually run on to a plot of land banked round so as to form a lagoon of 2 or 3 acres, and sufficiently large to contain about one day's sewage flow. The suspended matter left in the settled sewage after passing through the tank is almost entirely deposited here and the surface water drawn off at the foot of the plot, either direct or by earthen carriers, to the plots of land to be irrigated. The

MECHANICAL ANALYSIS.

Fine gravel (above 2 mm.)—medium sand (above 0.25 mm.)	...	...	...	...	...	14.87
Sand (0.25 – 0.05 mm.) – silt (0.05 – 0.01 mm.)	...	...	...	...	...	49.66
Dust (0.01—settling from water within twenty-four hours)—clay (still finer—precipitated by dilute nitric acid)	...	...	...	...	...	9.77
Loss on ignition (separate determination)	...	...	...	...	...	23.24
						97.54

The approximate number of particles in 1 gramme is 1,284,209,670, and in 1 c.c., 1,101,862,900.

The *Lime* (parts per 100,000) dissolved by water in twenty-four hours is, for soil, 0.045, subsoil 0.016, and dissolved by water saturated with carbonic acid in forty-eight hours, for soil 0.197, subsoil 0.068.

Acreage, Population, &c.

The total area of the farm is 75.5 acres, and of this 35 acres are available for sewage treatment. The average area under irrigation at one time is 17.5 acres; the population served is 18,000 (Altrincham 17,500, and Dunham Massey 500), which works out at 514 persons per irrigable acre, or 1,028 persons per acre for the average area irrigated. The normal dry-weather flow is 44.4 gallons per head per diem. The amount treated

lagoon method was found not to be practicable in hot weather, the scum rising from the bottom of the lagoon in floating masses and creating a nuisance. When the lagoon is first filled a portion of the impounded sewage filters through the soil to the under-drains, but the land soon silts up and will not pass any water through. After a lagoon has been used for three or four months it is dried, the sludge (about 3 in.) is ploughed in and a fresh lagoon made. The sewage and lagoon liquor is generally run on to the same plots intermittently for periods varying from fourteen to twenty-eight days, being turned on to the plots continuously for about twelve hours. In winter the sewage is sometimes applied to the land both night and day, without intermission. At such times there is considerable risk of the frost raising

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the banks or fenders of the lagoons and allowing the sewage to escape unpurified. Crude sewage is occasionally poured on the land from holes made in the main outfall sewer. *Cropping*.—There are 12 acres of osier beds, and these are sewaged alter-

however, is only used during very heavy storms when the sewage cannot be kept back. The principal crops are mangolds and cabbages, the mangolds being sown on ridges and the sewage run between them.

DATES OF VISITS, MEAN TEMPERATURES, RAINFALL, &c.					
Dates of Visits,	Mean Temperatures (deg. Fahr.).			Mean daily Rainfall (inches).	Remarks.
	Air.	Sewage.	Effluents.		
1900. April 26—May 16	50	50	49	·07	On three days the rainfall was ·45, ·32 and ·24 respectively. On three nights there were frosts, the lowest reading being 24.
1901. April 16—May 8	53	53	46	·02	On three days the rainfall was ·20 and ·12 twice.

nately, as a general rule by night only. The roots penetrate to a great depth, are apt to choke or displace the drains, consolidate the ground, rendering it difficult for the sewage to pass through,

Analyses— Sewage, Effluent and Stream.

The sewage is not screened and suffers but little settlement in the tank. The chief *Chemical* results are:—

CHEMICAL ANALYSES (PARTS PER 100,000 BY WEIGHT).				
	Sewage.*	Effluent, (14-18 samples.)	Stream. (2 samples.)	
Total nitrogen... ..	3.56	2.22	0.55 (?)	
Ammoniacal nitrogen	2.29	1.23	0.124	
Total organic nitrogen	1.24	0.26	—	
Albuminoid nitrogen	0.62	0.13 = { 79 per cent purification (approximate) }	0.081	
Oxygen absorbed 4 hours at 80 deg. Fahr. ...	5.22	1.75 = { 66.5 per cent purification (approximate) }	0.925	
Nitric and nitrous nitrogen... ..	—	0.76	0.33	
Chlorine (in water supply 1.03 and in subsoil water 1.54)	9.43	8.54 (?)	3.43	
Incubator test as judged by smell... ..	—	{ 81 per cent passed (16 samples) }	{ 1 earthy 1 sweet }	
Solids in suspension	—	—	—	

* No sets of hourly samples were taken, but only four chance samples of sewage and five of lagoon liquor, the latter being, if anything, the stronger. Any calculations as regards percentage purification which are made on the basis of these analyses must be very approximate indeed and of doubtful value.

and appear to encourage a dense growth of weeds, necessitating constant cleaning. The remainder of the irrigable land is arable, with the exception of a small piece of meadow near the brook, which,

The "effluents contained varying amounts of red-brown flocculent matter, no doubt mainly ferric hydroxide or basic carbonate, which gave to many of them a turbid appearance and a deep brown

Land Treatment of Sewage.

colour. Nos. 267 and 274 showed this more particularly; in No. 66 it is noted that the colour was due to iron and not to peaty matter, and this no doubt applies to the others also. After being filtered some of the effluents were just tinged, but others were still very brown. They had either no smell at all or an iron smell; in one or two instances the odour was so strong as to be suspicious, but the presence of so much iron necessarily made the characterisation of the smell more difficult than usual. There was much lime and much sulphate in solution, and also—as stated above—very considerable quantities of iron, mostly in the state of ferric hydroxide, partly in suspension and partly in solution; in the worse effluents some ferrous iron

far enough in relation to the total nitrogenous matter present. The effluents from the uncropped arable land were the least nitrated. The results showed that at the time of our observations the land was getting rather too much to do, but they also showed that it was capable of turning out good effluents. It should not be forgotten, in connection with this criticism, that at Altrincham some (though not much) storm water is also treated, and that the whole of the sludge from tank or lagoon is dug into the soil. . . . The rate of filtration at Altrincham is probably fairly rapid.” (Part II., page 51.)

The *Bacteriological* figures may be summarised as follows:—

BACTERIOLOGICAL ANALYSES (TOTAL NUMBER OF BACTERIA PER C.C.).			
---	Sewage. (9 samples.)	Effluent.* (15 samples.)	Stream.† (1 sample.)
(1) Gelatine at 20 deg. C.	13,820,000	363,400 { 97 per cent reduction }	53,000
(2) Agar at 37 deg. C.	1,570,222	7,275 { 99 per cent reduction }	6,700
(3) B. coli or closely allied forms (say at least)...	50,000	400 { Varied from at least 100 to 1,000, not 10,000 }	At least 100
(4) B. enteriditis sporogenes (spores—say at least)	70	4 { Varied from none in 1 c.c. to at least 10, but less than 100 }	{ At least 10, but less than 100 }
* Satisfactory (1) 5, (2) 10, (3) 9 and (4) 11 out of 15 effluents in each case. † Volume of brook water to effluent was about 6 to 1 when sample was drawn, but normally the ratio is about 3 to 1.			

was also present. Strictly speaking, they would have been the better for being strained or settled before being run into a brook. Besides affecting the smell, the presence of so much iron accounts for the comparatively small quantity of dissolved oxygen found in those effluents; under ordinary conditions effluents of this class ought to have contained more oxygen, although, on the other hand, it must be remembered that the Altrincham effluents come from a weak sewage, and would therefore tend to take up oxygen more rapidly than effluents of *apparently* the same chemical composition derived from a strong sewage. The dissolved oxygen test is therefore to a great extent discounted here.” (Part II., page 50.) “The Altrincham effluents were fairly satisfactory on the whole, but the nitrification was not carried quite

“Judged as a whole the results were certainly good, since the majority of the effluents passed the suggested standard for non-drinking-water streams. From Mr. Kershaw’s report it appears that although part of the farm is peat land, this land is not used for irrigation purposes. The area actually irrigated, although containing some peat, is of a sandier character. It is possible that the peat land, although considered unsuitable for sewage purification purposes, may exercise some restraining influence on the multiplication of the bacteria. But the satisfactory results are probably to be ascribed to the porosity of the surface soil, and the fine, white sand and gravel which Mr. Kershaw describes as immediately subjacent to it. Moreover, the sewage was in some respects not very strong, and was doubtless diluted by subsoil

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water gaining access to the sewers. Further, the fact that the main storm overflow acted, when the sewage was increased to less than twice the dry-weather flow, placed during wet weather less burden on the land than is perhaps usually the case in most sewage farms. In this connection the extremely foul character of samples 67 and 68 (storm-water overflow) may well be borne in mind. None of the effluents were in a fit state to be turned into a drinking-water stream." (Part III., page 47.)

Effluent and Stream Compared.

The ratio of effluent to brook water, normally, is approximately 1 to 3. The stream does not appear to be in a very satisfactory state, and contained (at the time of the visits to the farm) sewage weed for about 500 yds. below the lowest effluent outfall. The Sinderland Brook was polluted before it reached the farm—speaking generally the effluent must have had an oxidising effect upon it. This brook is frequently polluted by tan refuse. A large storm overflow culvert from another district also discharges into the stream, a little distance below the farm.

The amount of dissolved oxygen present when the samples were analysed (maximum = 1.3 c.c.) was small. It is difficult to estimate the oxygen in brown-coloured samples by the copper chloride method, but this does not apply to the earlier samples which were boiled out. In only one sample of water from the stream was the amount of dissolved oxygen at all great when the analysis was made. The iron in the effluent, &c., would also affect the figures adversely.

chief difficulty in working the farm is the want of sufficient land, and it is proposed to purchase 76.5 acres of the adjoining land, to construct new settling tanks and to enlarge the present outfall sewer.

Conclusions.

"The sewage (domestic) is weak. Even for a filtration farm Altrincham was treating a large volume of sewage, both per acre of the 'working' daily irrigable area and per acre of the total irrigable area, and although the sewage was weak, the farm was treating in the aggregate, so far as our data suffice for a comparison, a large quantity of organic matter. The soil and subsoil (porous peaty soil lying upon sand admixed with a little gravel) are not *apparently* of the best kind for purifying a large volume of sewage, especially when the average filtration depth downwards to the drains (only about 3 ft. 9 in.) is taken into consideration. At the same time the results which we have obtained from Altrincham lead us to consider, so far as our data go, that the aeration through the soil and subsoil must be better than would at first sight appear. The combined sewerage system is in operation, but the farm does not treat much storm water. The bacteriological results, apart from the total number of bacteria (gelatine at 20 deg. C.), do not admit of the conclusion that 46,000 gallons per acre (23,000 gallons per acre of the total irrigable area) is too large a volume of a weak sewage to be treated by settling and filtration through a peaty soil lying upon sand and gravel (that is, where the effluent is discharged into a non-drinking-water

DISSOLVED OXYGEN (PARTS PER 1,000 = C.C'S. PER LITRE).						
—	Boiled out.		Cuprous Chloride at time of			
			Drawing.		Analysis.	
Effluent	0.26—0.96	average 0.67	0.0	3.0 average 1.1	0.0—1.3	average 0.25
Stream	— —	3.03	— —	— —	— —	5.5*
Mixture	2.75—3.50	„ 3.13	— —	2.0	— —	0.0

* Stream in flood and dirty brown.
NOTE.—One sample was taken, but not analysed, when the brook was black as ink from tan liquor coming down.

Nuisance and Difficulties.

The only objectionable smell on the farm was that caused by the floating masses of scum on the lagoon surface previously alluded to. The

stream). The chemical results indicate that the land at present is somewhat overtaxed, and that with a smaller dose of sewage the results would be distinctly good." (Part I., page 83.)

Land Treatment of Sewage.

LATER WORK.

The new works referred to in the Engineering Report (Part IV.) have been carried out. The total area of the farm is now 150 acres, the irri-

gable area 70 acres, and the average area irrigated at one time 20 to 25 acres. The sewage is screened before being pumped into four tanks, each 120 ft. by 30 ft. by 6 ft. 6 in. average depth. Two new main carriers have been constructed.

CAMBRIDGE.

HISTORY.

The farm is of recent date, and beyond the reference to lime treatment (see *Soil*) there is nothing noteworthy to record. In "Sewage Treatment and Disposal," by Thomas Wardle (?1893), reference is made to the suggestion that 640 acres or so at Shesterton Fen should be laid out for a sewage farm. Although the *British Medical Journal* thought it would be a good plan, the author did not agree (p. 120). It will be seen that the scheme was abandoned.

REPORTS TO THE ROYAL COMMISSION.

Conservancy.—There are very few privies, and the night soil from these is taken by farmers.

The Sewage. *Separate or Combined.*—The town is only partially on the separate system. All water from back-yards and back parts of roofs goes to the foul-water sewers. *Domestic.*—The sewage is practically domestic, but there is a small quantity of effluent from two breweries. *Subsoil Water.*—In normal dry weather the subsoil water amounts to about 40 per cent (say 900,000 gallons per diem), due to faulty sewers. After heavy storms the sewage flow at times does not return to normal for some days in consequence of the excess of subsoil water finding its way into the sewers. The normal *Dry-weather Flow*, including subsoil water, is 2,250,000 gallons per diem, and the *Storm Flow* has reached 5,000,000 gallons for twenty-four hours. The storm water is now treated on coarse clinker beds at the pumping station, and, consequently, the amount received at the farm during storms is not greatly in excess of the normal flow. The *Water Supply* is about 24 gallons per head, obtained from wells in the chalk marl, greensand and the chalk. The *Rainfall* averages 21 in. per annum, and the *Drainage Area* of districts sewered is 1,500 acres. *Flushing.*—The sewers are flushed quarterly with waterworks water. *Stay in Sewers.*—The sewage takes about one hour to flow from the centre of Cambridge to the pumping

station, a *Distance* of $1\frac{1}{2}$ miles. *Sewer Capacity.*—The whole of the sewage gravitates to the pumps through a 4 ft. 3 in. by 2 ft. 10 in. sewer, laid at a gradient of about 1 in 870; its theoretical capacity, running full, being 2,060 c.f.m. There are five *Storm Overflows* discharging into the Cam on either side of the pumping station; they have only once come into operation during the last 8 years; the sewage has to rise about 30 ft. in the pump well before an overflow takes place, and this would back up the water in the outfall sewer, flooding some portions of the town. *Screens.*—The sewage passes through a cage screen before reaching the pump well. *Pumps.*—From the pumping station the sewage is pumped to the farm in a 24-in. cast-iron rising main 2 miles long. The lift is 44 ft., and the sewage takes about 40 minutes to reach the farm. There is only one *Settling Tank*, 61 ft. by 39 ft. by about 3 ft. average depth, with a capacity of about 45,000 gallons. It is worked on the continuous system and is cleaned out twice a week, the operation taking but a short time. The *Stay in Tank* is only about 30 minutes. The *Screenings* are burnt in the destructor, which is used for disposing of the town's refuse and at the same time for supplying steam for pumping purposes. The *Sludge* is run into oblong sludge beds lying alongside the carrier embankments; it is subsequently dug in. It is also passed over other portions of the land where wanted. Approximately 35 tons of wet sludge are produced a week, but the quantity varies considerably. A reference to *Buried Sludge* will be made hereafter. The *Analyses*, both chemical and bacteriological, of the sewage will be found at the end of this section compared with those of the effluent and of the stream.

Soil and Subsoil.

The *Soil* consists of 12 in. to 15 in. of sandy loam. On plot 4 (nearly 5 acres) 100 tons of fine destructor ash have been ploughed in on account of the quantity of sludge used. The lime process was employed for two and a half years (commencing 1895), lime

Land Treatment of Sewage.

being added at a rate, first of all, of 15 grains per gallon; subsequently this amount was reduced to 11, 10, and finally 8 grains per gallon. This treat-

The *Mechanical Analysis* shows the following percentage composition of the ignited soil and subsoil:—

MECHANICAL ANALYSIS.										Soil.	Subsoil.
—											
Gravel (above 8 mm.)	...	...	...	...	...	...	...	...	...	—	20·87
Fine gravel (above 2 mm.) — medium sand (above 0·25 mm.)	...	...	...	...	...	...	...	...	...	11·76	34·76
Sand (0·25 — 0·05 mm.) — silt (0·05 — 0·01 mm.)	...	...	...	...	...	...	...	...	...	74·99	40·42
Dust (0·01 mm. — settling from water within twenty-four hours) — clay (still finer precipitated by dilute nitric acid)	...	...	...	...	...	...	...	...	...	7·06	1·38
Loss on ignition (separate determination)	...	...	...	...	...	...	...	...	...	5·00	1·20
										98·81	98·63

ment was, however, eventually abandoned in November, 1898, as it was found that the farm was rapidly being choked for filtration purposes. The *Subsoil* is a compact stratum of gravel and sand overlying the gault clay, which is found at a depth of 7 ft. to 12 ft. below the surface. About 2 ft. to 2 ft. 6 in. from the surface soil a vein of sand, impregnated with iron, occurs in parts. *Under-drainage*.—The entire farm is under-drained, and the pipes are laid at a depth of from 3 ft. 6 in. to 6 ft., and about 50 ft. apart. On plot 4 the drains are only 16 ft. 6 in. distant from each other, and on plot 11 ($3\frac{1}{2}$ acres) 14 ft., with a view of increasing the rate of filtration. The feeder drains are ordinary 4-in. butt agricultural pipes, laid herring-bone chiefly, and are connected up to 12-in., 18-in. and 21-in. socketted stoneware master-drains, which in turn flow into a 24-in. main effluent drain. *Subsoil*

The approximate number of particles in 1 gramme is for soil 614,122,600, subsoil 176,087,960; and in 1 c.c. for soil 880,665,516, subsoil 320,657,693.

The *Lime* (parts per 100,000) dissolved by water in twenty-four hours is for soil 0·085, subsoil 0·058; and dissolved by water saturated with carbonic acid in forty-eight hours, for soil 0·530, subsoil 0·582.

Acreage, Population, &c.

The total area of the farm is 102·5 acres, and of this 74 acres are available for sewage treatment. The average area under irrigation at one time is 18·5 acres; the population served is 50,000, which works out at 676 persons per irrigable acre, or 2,703 persons per acre for the average area irrigated. The normal dry-weather flow is 45 gallons per head per diem. The amount treated per acre for twenty-four

DATES OF VISITS, MEAN TEMPERATURES, RAINFALL, &c.					
Dates of Visits.	Mean Temperatures (deg. Fahr.).			Mean daily Rainfall (inches).	Remarks.
	Air.	Sewage.	Effluents.		
1901. January 8—February 6	37	38	39	·02	{ 22 rainfall on January 27th. Slight snow on five days. Several frosts occurred freezing the sewage standing on the plots Twenty-four hours' sewage samples
1902. February 25-27	—	—	—	·10	

Water and Floods.—The subsoil water in dry weather lies at a depth of 6 ft. to 7 ft. from the ground level. The farm is not liable to floods.

hours at the normal rate of flow is 121,600 gallons on the average area irrigated, equal to 30,400 gallons on the whole irrigable area.

Cambridge.

Treatment and Cropping.

Treatment.—The farm is divided into plots of a convenient size, ranging from about 3 acres to 6 acres each, and they are laid out perfectly level, the carrier embankments forming an enclosure on three sides and the remaining side being banked up or fendered to retain the sewage, which is only treated once through the land. "The practice followed in irrigating is to flood the sewage on to the plots from the carrier outlets, running it on continuously night and day for about four days to a week, the plots then being allowed to dry as long as possible. In the case of two fields (Nos. 4 and 11) which are used as natural filter-beds, manholes and

is used and only a portion of a plot utilised for sewage." (Part IV., page 45.) *Cropping.*—Very few crops are grown on the farm; kohlrabi, mangolds and horse-corn are cultivated and the produce is sold. A large portion of the farm is always uncropped—*i.e.*, the soil is mainly used as a bacterial filter.

Analyses— Sewage, Effluent and Stream.

The sewage is rather weak and arrives at the farm well broken up. Although there is only about half an hour's settlement in the one tank at the farm, some 35 tons of sewage sludge are obtained each week. The chief *Chemical* results are :—

CHEMICAL ANALYSES (PARTS PER 100,000 BY WEIGHT).			
	Sewage.*	Effluent. (17-18 samples.)	Stream. (2 samples.)
Total nitrogen	4.60	2.09	0.61 (?)
Ammoniacal nitrogen	2.94	0.65	0.025
Total organic nitrogen	1.51	0.21	0.085
Albuminoid nitrogen	0.73	0.09	0.035
Oxygen absorbed 4 hours at 80 deg. Fahr. ...	8.15	0.81	0.475
Nitric and nitrous nitrogen	—	1.26	0.5
Chlorine (in water supply 1.91, and in subsoil water 1.60)	7.15	7.55	2.06 (1 sample)
Incubator test as judged by smell	—	{ 94 per cent passed (18 samples) }	Sweet
Solids in suspension (hourly samples only) ...	26.5	—	—

* Approximate average of three sets of sample drawn in equal quantities per hour for twenty-four hours and of five chance samples.

penstocks are provided by means of which the sewage can be held in contact with the soil for some hours. These plots are sewaged continuously for about six hours a day. Some plots which have been sewaged longer than others will not pass so much sewage owing to the scum formed on the surface, and therefore the sewage has to be shut off sooner from them, and other plots with less scum receive the surplus sewage. The surface scum has a beneficial effect, by checking filtration when the plot is becoming sludged up and so preventing the land from becoming sewage sick. When the land is sufficiently dry to admit of it, a light spring scarifier has been found of great assistance in breaking up this surface skin of sludge. Occasionally a stank*

* By stank is meant a small embankment, or fender, to retain the sewage within certain limits.

"The effluents were partly clear and colourless, and with no sediment, these being as a rule the effluents from special plots; partly slightly opalescent and of a brownish tinge, with a little red, brown or grey flocculent matter, and in two cases with a considerable green deposit; partly rather turbid, this turbidity being no doubt mostly due to the separation of carbonate of lime from solution. The dimness was not, however, a criterion of purity or otherwise. Samples Nos. 204 and 205 were both dim, but the first was good and the second bad. All of them had a clean smell when they came to be analysed, though in two cases it was fishy, and in five others slightly fishy. The reaction was alkaline. Two effluents were tested for lime in solution, and, as was to be expected, a very large quantity of this was found to be present, together with a consider-

Land Treatment of Sewage.

able amount of sulphate. One effluent out of two tested showed a small amount of ferrous iron in solution." (Part II., pages 70 and 71.) "It will be seen that the Cambridge sewage farm treats, on a good porous soil and subsoil, an *exceptionally large* volume of a rather dilute sewage per acre, and at

effluents failed to pass the suggested biological standards. But the percentage degree of purification effected in the effluents as compared with the crude sewage was striking; and as the majority of the effluents either passed or came within measurable distance of passing the standards laid down,

BACTERIOLOGICAL ANALYSES (TOTAL NUMBER OF BACTERIA PER C.C.).				
—				
	Sewage. (4 samples.)	Effluent.* (14 samples.)	Stream. (1 sample.)	
(1) Gelatine at 20 deg. C.	11,990,000	711,476 { 94 per cent re- duction }	38,000	
(2) Agar at 37 deg. C.	1,602,500	78,327 { 95 per cent re- duction }	1,400	
(3) B. coli or closely allied forms (say at least)	77,500	2,100 { Varied from at least 100 to at least 10,000 }	10 not 100	
(4) B. enteriditis sporogenes (spores — say at least)	100	15 { Varied from at least 1 but less than 10 to at least 100 but less than 1,000 }	At least 1 but less than 10	

* Satisfactory, (1) 4 out of 13, (2) 3 out of 14, (3) 3 out of 14, and (4) 2 out of 14 effluents.

the same time an exceptionally large absolute amount of organic matter, and produces from it a (dilute) effluent which is usually good, and in some instances exceedingly good. At the same time it is clear that the organic matter left in some of the less purified effluents is of a somewhat putrescible character, as judged by the incubator test, though there is nearly always enough nitrate present to keep the liquid sweet upon incubation." (Part II., page 75.)

The *Bacteriological* figures may be summarised as above.

there is no reason to doubt that land of the kind available at Cambridge could be worked so as uniformly to yield a satisfactory effluent. This would doubtless involve the acquisition of an additional area of land to treat the same volume of sewage; but the additional amount of land required for this purpose would not in all probability be so great as not to compensate by the improved condition of the effluent for the additional outlay. The very variable quality of the effluents, some being very good, others bad, suggests the possibility, if not the practicability, of obtaining by some means

DISSOLVED OXYGEN (PARTS PER 1,000 = C.C'S. PER LITRE).									
—				Boiled out.	Cuprous Chloride at time of				
					Drawing.			Analysis.	
Effluent	...	...	...	—	0·5–4·0 average 2·03			0·0–2·4 average 0·89	
Stream	...	...	...	—	7·0–7·0 „ 7·0			4·0–6·25 „ 5·13	
Mixture	...	...	...	—	5·5–6·5 „ 6·0			0·5–6·5 „ 3·5	

“None of the effluents were in a fit state to be turned into a drinking-water stream. As regards non-drinking-water rivers, the majority of the

uniformly good results. As it appears from Mr. Kershaw's notes that the farm is very well managed, the acquisition of an additional area of land would

Cambridge.

seem to be the best solution of the problem. It must be borne in mind that, although the sewage was dilute, the volume of sewage treated per acre was exceptionally great." (Part III., page 60.)

Effluent and Stream Compared. The effluent does not appear to vary much in character, and its normal ratio to the river water is 1 to 15. A small quantity of sewage fungus was noticeable at times issuing from the main effluent outfall, which has a submerged outlet. The river Cam was in fair condition in January and February, 1901. The comparatively large volume of river water minimises any effect that the effluent may exert upon it.

The dissolved oxygen in the effluents was generally small. In three out of four samples taken from the stream incubation did not by any means exhaust the dissolved oxygen; in the fourth, which was drawn 100 yards below the effluent outfall, the dissolved oxygen was practically exhausted after incubation, but plenty of nitrate remained. (See table on page 26.)

Nuisance and Difficulties. There is very little smell arising from the sewage operations. The chief difficulty in working the farm is to keep the top soil loosened, as it cannot always be ploughed in the winter. After ploughing subsoiling with a scarifier has been found of great assistance. During summer the land is kept ploughed as frequently as possible.

Conclusions. "The sewage (mainly domestic) is rather weak, and is treated for the most part on uncropped land. In this respect the farm differs from the others. Even for a filtration farm Cambridge was treating an *exceptionally large volume* of sewage both per acre of the 'working' daily irrigable area and per acre of the total irrigable area. It was also treating in the aggregate a large amount of organic matter, but it must be remembered that this organic matter was highly diluted. Nevertheless, the soil and subsoil (sandy loam overlying gravel and sand) are admirably adapted for the purification of a large volume of sewage, and the average filtration depth down to the drains is nearly 5 ft. The sewerage

system is partially separate, and very little storm water reaches the farm. In conclusion, we consider that 121,600 gallons per acre per twenty-four hours (30,400 gallons per acre of the total irrigable area per twenty-four hours) is rather too large a volume of even a weak sewage to be treated by screening, settling and filtration through even 5 ft. of a soil and subsoil admirably adapted for purification purposes. It should be borne in mind here that it is easier to bring a weak sewage down to an absolute standard of purity (such, for example, as the Mersey and Irwell) than a strong sewage (volume for volume), although in the former case the liquid has really undergone less purification." (Part I., page 85.)

LATER WORK.

Application has been made for a loan for further works — namely, a tank to hold about 225,000 gallons at the farm and in conjunction with the pumping station further storm-water beds. The following remarks will bear repetition: "In the case of two fields (Nos. 4 and 11) which are used as natural filter-beds, manholes and penstocks are provided by means of which the sewage can be held in contact with the soil for some hours. These plots are sewage treated continuously for about six hours a day." This alteration in the method of treatment has been continued, and about one-third of the farm is now being worked in this manner. The description "bacterial areas" has been applied to these plots. On two other fields, together about 9½ acres, the land has been divided into three sections, sewage being so applied that it floods the first portion and rises after filtration, floods the second portion and finally percolates through the third portion. This allows of a very large amount of sewage being treated on a small area. It is still necessary to leave much of the land uncropped, and in view of the exceptional quantity of sewage dealt with per acre no other course seems possible. The banks of the carriers have been planted with fruit trees. Some excellent crops of horse-beans have been garnered, and I understand that the holding-up, as far as possible, of the liquid in the soil has a very beneficial effect on root crops. A portion of the sludge, after drying for some time, is now disposed of to local farmers.

CROYDON.

HISTORY.

The following extracts from the Rivers Pollution Commission, First Report, Vol. I., pages 87 to 89 (1870), will be of interest:—

“At the Beddington meadows below Croydon 260 acres of an open soil upon a gravelly subsoil have for the last seven years received the drainage water of from 30,000 to 40,000 people. The water supply of Croydon and the copious land drainage of the place together yield a quantity of sewage equal to at least 3,000,000, sometimes exceeding 5,000,000, gallons daily . . . Watercresses, too, have proved here an excellent crop for sewageing, not only from the profit derived from them, but from their cleansing powers upon the dirty liquid.”

Mr. Marriage (the tenant) paid the rent and also “a profit rent of £1 per acre per annum for the use of the sewage.” Periodical analyses extending over a whole year (September 24, 1868, to September 24, 1869) were made, and I have worked out the average for the effluents (see No. 2 below). Figures are given of samples taken on December 23 and 30, 1869 (see Nos. 3 and 4 below):—

tity.” The reference to the successful cultivation of watercress will show how different the views with regard to sewage disposal were in 1870 from those in vogue in 1906. In “Sewage Disposal Works,” by W. Santo Crimp (1890, first edition), it is stated “For several years the corporation have given up keeping cattle, but have taken horses and cattle in to graze. A dairy farmer has erected buildings upon the farm, in which about 200 milking cows are kept which consume large quantities of sewage-grown produce” (page 129).

REPORTS TO THE ROYAL COMMISSION.

Separate or Combined.—The **The Sewage.** separate system is used on about half the drainage area for water from roads and front roofs; back roofs and back-yards drain into the foul-water sewers. The streets are chiefly macadam. *Domestic or Mixed.*—The sewage is almost entirely domestic; about 2 per cent, say 80,000 gallons, is received per diem of laundry, brewery and butchers' effluents. It is estimated that about one-fourth of the sewage is

SEWAGE AND EFFLUENTS (PARTS PER 100,000).										
—		Total Solid Matters in Solution.	Organic Nitrogen.	Ammonia.	Nitrogen as Nitrates and Nitrites.	Total Combined Nitrogen.	Chlorine.	Suspended Matters.		
								Mineral.	Organic.	Total.
(1) Sewage	...	45.7	1.576	3.006	.000	3.527	4.23	—	—	—
(2) Effluents	...	38.4	.128	.131	.363	0.584	2.67	—	—	—
(3) Sewage	...	48.0	1.009	2.692	.0	3.226	4.35	2.88	8.72	11.60
(4) Effluents	...	48.7	.074	.398	.921	1.322	3.33	Trace	Trace	Trace

“Only on one occasion (August 12, 1869) during the entire year was the effluent water discharged in a somewhat unsatisfactory condition. . . . Suspended matters were never present except in minute quan-

Subsoil Water. The normal *Dry-weather Flow* is 4,000,000 gallons, being 3,000,000 gallons from Croydon and 1,000,000 gallons from Thornton Heath and Norbury. The *Storm Flow* in times

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of heavy storms sometimes reaches 16,000,000 gallons per twenty-four hours. The *Water Supply* is about 28 gallons per head per diem; the greater part is obtained from corporation wells in the chalk, the remainder from the Lambeth Water Company (now the Metropolitan Water Board). The average *Rainfall* is 23·6 in., and the *Drainage Area* of the district sewered is 6,300 acres. *Flushing*.—The sewers are flushed from large automatic tanks, tipping tanks and flushing vans and hose. The *Stay in Sewers* is on the average some two hours, the *Distance* being about 3 miles. The *Sewer Capacity*, running full (two outfalls), is 5,814 c.f.m. *Screens*.—The Croydon sewage passes through one of Latham's patent solid sewage extractors. They

gravel and sand 6 ft. to 12 ft. deep; iron pan, more or less impervious, appears in parts. *Under-drainage*.—Only about 100 acres of the farm are under-drained; the pipes were put in to assist the land to dry after the sewage was taken off. The drains vary in depth from 4 ft. to 9 ft. and from 4 in. to 20 in. in diameter; they are usually very wide apart, but the distances differ. This work was executed about 1886. *Subsoil Water and Floods*.—There is not much subsoil water on the farm, and it is not subject to flooding.

The *Mechanical Analysis* shows the following percentage composition of the ignited soil and the un-ignited subsoil (this subsoil gave very little loss on ignition):—

MECHANICAL ANALYSIS.			
—		Soil.	Subsoil.
Gravel and stones (say, above 8 mm. in the soil, and 30 to 8 mm. in the subsoil)	...	22·67	57·47
Fine gravel (above 2 mm.)—medium sand (above 0·25 mm.)		14·06	24·99
Sand (0·25—0·05 mm.)—silt (0·05—0·01 mm.)		51·67	15·14
Dust (0·01 mm. — settling from water within twenty-four hours) — clay (still finer precipitated by dilute nitric acid)		6·13	2·73
Loss on ignition		5·46	—
		99·99	100·33

are in duplicate, worked by a turbine, the sewage itself providing the motive power. The extractor may be briefly described as resembling a circular wire sieve, revolving on a horizontal axis; the sewage flowing through the meshes leaves the solids in the sieve and a revolving screw passes the solid matter into a trough. The Norbury and Thornton Heath sewage is screened. *Settling Tanks*.—The Thornton Heath and Norbury sewage passes through two small settling tanks, each 32 ft. by 9 ft. by 1 ft. average depth, provided with scum boards; both are used together on the continuous method. The *Screenings* and *Sludge* (about 25 tons, wet, weekly) are ploughed or dug into the land. The *Analyses*, both chemical and bacteriological, of the sewage will be found at the end of this section compared with those of the effluent and of the stream.

Soil and Subsoil. The *Soil* is from 12 in. to 18 in. deep, varying from loam, interspersed with gravel, to land of a somewhat lighter character. The *Subsoil* is chiefly

The approximate number of particles in 1 gramme is for soil 368,297,690, subsoil 160,510,970; and in 1 c.c. for soil 520,775,170, subsoil 295,828,280.

The *Lime* (parts per 100,000) dissolved by water in twenty-four hours is for soil 0·029, subsoil 0·026; and dissolved by water saturated with carbonic acid in forty-eight hours, for soil 0·215, subsoil 0·268.

Acreage, Population, &c. The total area of the farm is 673·5 acres, and of this 420 acres are available for sewage treatment. The average area under irrigation at one time is about 70 acres; the population served is 100,000 (Croydon 75,000, Thornton Heath and Norbury 25,000), which works out at 238 persons per irrigable acre, or 1,428 persons per acre for the average area irrigated. The normal dry-weather flow is 40 gallons per head per diem. The amount treated per acre for twenty-four hours at the normal rate of flow is 57,120 gallons on the average area irrigated, equal to 9,520 gallons on the whole irrigable area.

Croydon.

Treatment and Cropping. The mode of *Treatment* is to apply the sewage to arable land (usually, not invariably) and then to pass it over one or two, and, occasionally, three, further plots. It is distributed from concrete

be sewage. In 1900 about one-half of the irrigable area was rye-grass, 100 acres permanent pasture (which is also irrigable), and about 100 acres of arable land. The crops are utilised in part on the farm premises and partly sold.

DATES OF VISITS, MEAN TEMPERATURES, RAINFALL, &c.					
Dates of Visits.	Mean Temperatures (deg. Fahr.).			Mean daily Rainfall (inches).	Remarks.
	Air.	Sewage.	Effluents.		
1900. February 12-26	39	49	42	·10	{ On six occasions the rainfall exceeded ·25, the greatest falls being ·46, ·35 (rain and snow) and ·32 ·42 rainfall on October 5th Experiment
October 3-18	50	59	55	·03	
October 24—November 10	50	58	54	·07	
1901. October 7-11	—	58	54	·006	—
1902. January 1-7	—	—	—	·036	Twenty-four hours' sewage samples

carriers into plough-cuts about 50 ft. apart; these terminate before the end of the plot is reached and the land between is dished. Sewage is applied continuously for twenty-four hours, and the land is then allowed to dry for two or three days. In wet weather, however, it is necessary to use the same land for three to five days in succession. The

Analyses— Sewage, Effluent and Stream.

The whole of the sewage is screened, and, in addition, one-quarter of it passes through small settling tanks, in which, however, the settlement is very inadequate. It arrives at the farm well broken up as a rule. The chief *Chemical* results are :—

CHEMICAL ANALYSES (PARTS PER 100,000 BY WEIGHT).			
—	Sewage.*	Effluent. (15-16 samples.)	Stream. (1 sample.)
Total nitrogen	8·34	2·20	0·741
Ammoniacal nitrogen	5·81	1·48	0·007
Total organic nitrogen	2·61	0·26	0·026
Albuminoid nitrogen	1·28	0·14 { 88·1 per cent purification (average) }	0·011
Oxygen absorbed 4 hours at 80 deg. Fahr.	13·09	1·41 { 89·2 per cent purification (average) }	0·85
Nitric and nitrous nitrogen	—	0·37	—
Chlorine (in water supply 1·3, and in subsoil water —)	8·25	7·52 (?)	0·708 1·52
Incubator test as judged by smell	—	{ 73 per cent passed (15 samples) }	Sweet
Solids in suspension (hourly samples only)	34·5	—	—

* Approximate averages of seven sets of samples drawn in equal quantities per hour for twenty-four hours and of five to seven chance samples.

Experiment will be dealt with hereafter. *Cropping.*—Italian rye-grass is the chief crop, mangolds, cabbages and oats are also grown; the oats cannot

“These effluents varied a good deal in appearance, some of them being clear and almost colourless, and to all appearance excellent effluents; others of a

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yellowish to brownish tint, with but a very small amount of suspended solid of one kind or another; while in others the liquid was turbid, with very considerable quantities of suspended solids. Three-fourths of them may, however, be taken as very free from matter in suspension. Nos. 39a and 44, for instance, belong to the category of turbid samples; they were drawn during rain—*i.e.*, contained much storm water. No. 380, also turbid, showed no precipitated sediment, but a large quantity came down in the centrifuge. This last sample was not drawn during rain, but was insufficiently purified. Those few notes with regard to the appearance of the Beddington final and general effluents are, I think, sufficient in themselves to indicate the difficulty of treating largely fluctuating volumes of liquid (sewage plus storm water) by surface irrigation. Three-fourths of the effluents had a good clean smell when they came to be analysed, but No. 153 (a bad sample) had a faint sewage (?) smell, No. 380 (also bad) a fishy smell, and Nos. 39 and 44 (fair) a fishy-earthly smell. All that were tried for reaction were

with our present data it is impossible to say how much of the purification effected at Beddington is due to filtration through the top soil and how much to surface irrigation pure and simple. The sewage is practically a domestic one of moderate strength, probably of about average strength. The volume of sewage treated per acre, exclusive of storm water, was very large for a (mainly) surface irrigation farm . . . The analytical results of the final and general effluents show that the Beddington farm, used for surface irrigation under the conditions detailed in the engineering report, is capable of producing a high-class effluent, chemically speaking, and does so sometimes but not always. Hence one must infer that the land was rather overdosed with sewage at the time the observations were made. The irregularity caused by the intermittent flushes of storm-water sewage in varying quantity no doubt adds much to the difficulty of treatment." (Part II., page 102.)

The *Bacteriological* figures may be summarised as follows:—

BACTERIOLOGICAL ANALYSES (TOTAL NUMBER OF BACTERIA PER C.C.).				
—	Sewage. (6 samplee.)	Effluent.* (10 samplee.)	Stream. (1 sample.)	
(1) Gelatine at 20 deg. C. 	29,000,000	1,413,200 { 95 per cent reduction }	72,000	
(2) Agar at 37 deg. C	5,315,000	112,240 { 97 per cent reduction }	2,680	
(3) B. coli or closely allied forms (say at least)... 	100,000	3,241 { Varied from 10 not 100 to 10,000, not 100,000 }	10 not 100	
(4) B. enteriditis sporogenes (spores—say at least) 	850	23 { Varied from none in $\frac{1}{10}$ c.c. to at least 100, but less than 1,000 }	None in 1 c.c.	
* Satisfactory (1) 3, (2) 6, (3) 5 and (4) 5 out of 10 effluents in each case.				

alkaline, and the three tested qualitatively showed much lime and a good deal of sulphate in solution . . . The *dissolved oxygen* present when the samples came to be analysed varied very much, but half of the effluents were then well aerated—*i.e.*, contained from 4 c.c. upwards of dissolved oxygen per litre—a point in their favour." (Part II., page 98.) "Since the surface soil at Beddington is about 15 in. deep, and is, moreover, of very good quality for sewage purification, we are to some extent dealing here with a shallow filtration farm . . . But

"Considered from the bacteriological point of view, none of the effluents were in a fit state to be turned into a drinking-water stream . . . About half the effluents were satisfactory [non-drinking-water streams]. The average results were by no means so unsatisfactory as to indicate the impracticability of working land of the kind available at Beddington, so as uniformly to yield a reasonably good effluent. The fact that some of the effluents yielded such good results leads to the belief that, dealing with the same volume of sewage, the acquisition

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of a somewhat larger area of land might result in the production of effluents of a uniformly satisfactory character. Possibly, if the farm, instead of dealing with the total bulk of storm water, dealt only with the same proportion of storm water relative to dry-weather flow as is dealt with on many sewage farms, the results would be much more satisfactory. It ought to be remembered that a large access of storm water not only at the time of its introduction affects injuriously the working of a sewage farm, but may also so disturb the equilibrium of the biological conditions which make for purification of the sewage as to exercise a more lasting prejudicial effect." (Part III., page 73.)

Effluent and Stream Compared.

The normal ratio of effluent to river water is 1 to 8; at the first time of sampling it was 1 to 12. Judged by a non-drinking-water standard, little or

Nuisance and Difficulties.

There is, as a rule, no objectionable smell noticeable in the working of the farm. Occasionally, in hot weather, a certain amount of smell is traceable to some of the carriers, caused by offensive matter being arrested by the coarse herbage getting into the carriers when not kept down sufficiently. The channel from the point where the sewage enters the farm is not concreted for some distance, and this renders effectual cleaning out a difficult matter, the bottom and sides being gravel and apt to become overgrown. The chief difficulties in the working of the farm are the selling of the crops, and also the disposal of storm water in time of storms, all being treated on the land. In wet weather, too, solids wash on to the rye grass in masses and are extremely difficult to get rid of; further, large quantities of grease and scum are carried out of the sewers.

DISSOLVED OXYGEN (PARTS PER 1,000 = C.C.'S PER LITRE).

	Boiled out.	Cuprous Chloride at time of	
		Drawing.	Analysis.
Effluent	1.28 - 7.64* average 4.47	1.0 - 6.25 average 3.81	0.0 - 6.5 average 3.05
Stream	— — 7.52	— — 6.25	6.0 - 7.0 " 6.36
Mixture	3.51 - 6.34 „ 4.93	— — —	6.8 - 7.7 „ 7.3

* This is a remarkable figure. It almost represents saturation at the temperature at which the effluent was drawn (51 deg. Fahr.).
N.B.—The standard copper tubes had weakened, and some of the figures obtained are, therefore, too high.

no fault was, on the whole, to be found with the water of the river Wandle in February and October, 1900, though the samples examined were not altogether free from flocculent matter. Here, again, we have a comparatively large volume of river water as compared with that of the effluent. There is evidently no nuisance derived from the mixture of effluent and river water.

Speaking broadly, six of the effluents required nothing further to preserve them from putrefaction (upon incubation) than the dissolved oxygen that they already contained—in most cases not very much—and this, of course, ranks them as good. The three samples of water from the stream that were jointed and incubated before analysis were all very well aerated and maintained their dissolved oxygen excellently.

Conclusions. "The sewage (almost purely domestic) is of medium strength.

For a combined surface irrigation and filtration farm, Beddington was treating a very large volume of sewage per acre of the 'working' daily irrigable area, and also a large volume per acre of the total irrigable area. As regards organic matter, it was treating a little less than Rugby in the aggregate, owing to the sewage being much weaker. The soil and subsoil (light gravelly loam over gravel and sand) are of a kind well adapted for purifying a large volume of sewage by filtration. Beddington, however, is worked mainly as a surface irrigation farm. But it is probable that, owing to the porosity of the soil, the surface irrigation at Beddington is supplemented by some filtration through the surface soil. The sewerage system is

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partially separate, and all the storm water reaching the sewers is dealt with on the farm. As the volume of this is at times very considerable, it is obvious that the regular working of the farm must be materially interfered with, and this may account for the fact that the effluents varied in quality to a considerable extent. We are of opinion that 57,100 gallons per acre per twenty-four hours (9,500 per acre of the total irrigable area) is too large a volume of even a medium-strength sewage to be treated by screening and surface irrigation even over such a porous soil. The volume of sewage dealt with per acre of the 'working' daily irrigable area was very large, owing to the 'resting' area being five times the 'working' area. The bacteriological results were, generally speaking, less satisfactory than the chemical. The fact of the Beddington soil and sub-soil being fairly comparable in quality with those at Nottingham and Cambridge, taken together with the filtration results obtained from the 'special experiment,' leaves no room for doubt that the above-mentioned volume of sewage could be satisfactorily treated if Beddington were laid out as a filtration farm." (Part I., page 87.)

LATER WORK.

In 1901-2 a pumping station was erected to deal with the dry-weather flow only from the Norbury sewer. The sewage was directed into seven bacteria beds, each 226 ft. by 56 ft., filled with coarse gravel to a depth of 4 ft. They were worked upon the contact principle, and were fitted with automatic gear for filling and discharging. In 1902 two tanks were added, each 125 ft. by 22 ft. by 12 ft. deep, and subsequently a further tank was built, 125 ft. by 56 ft. by 12 ft. deep. The sewage flowed consecutively through these tanks before reaching the

contact beds. In 1904 these arrangements were condemned, and their failure was attributed in large measure to the improper method of working. A small experimental continuous filter, one half of which was gravel and the other half clinker, has been in use for some little time. The population has considerably augmented, and at the present time the sewage from over 85,000 persons is dealt with at the Croydon outfall and over 35,000 at the Norbury outfall. The works at the Norbury outfall are in course of reconstruction. The beds are being divided into four sections each, and twenty-eight sprinklers will be employed to distribute the sewage after passing through the tanks, which will be worked more or less on the septic principle, being cleaned out about once a month. A new 15-in. cast-iron main will be laid to an area of 44 acres, not previously irrigated, at a distance of $1\frac{1}{4}$ miles.

The following works have been planned for the treatment of the sewage from the Croydon outfall: A diversion of the main outfall sewer to a screening-house; three tanks (for the ordinary flow) of a total combined capacity of 600,000 gallons; twenty-four continuous filters, each 80 ft. diameter by 6 ft. deep, to be filled with gravel and clinker; a main to convey the sludge to various fields on the farm; the utilisation of about 45 acres of additional land; and three tanks, also 600,000 gallons capacity, to deal with storm water, which after passing through them would return to the old culvert and be treated as heretofore.

A large number of dairy cows is kept, and in this manner the bulk of the rye-grass can be disposed of. Formerly there was a good market for this typical sewage farm product, but of late years it has steadily declined.

LEICESTER.

HISTORY.

Sewage was first pumped to the farm at the end of September, 1890. Some details with regard to the laying out will be found under the sub-heading *Treatment and Cropping*. "For several years the effluents were uniformly satisfactory and quite equal to acknowledged satisfactory standards. The following analysis, taken in October and December, 1891—namely, twelve to fifteen months after the farm had been in operation, is a fair average: Albuminoid ammonia 0·09 grain per gallon and oxygen absorbed 0·562 grain per gallon." [0·13 and 0·8 parts per 100,000.] (R.C.S.D., Answer 8,110.)

REPORTS TO THE ROYAL COMMISSION.

The Sewage. *Conservancy.*—Though a certain number of privies and pail-closets (under 5,000) remain, the town is chiefly served by water-closets (about 37,000)—the house slop water, however, in all cases flows to the sewers. *Separate or Combined.*—The sewerage is chiefly on the combined system, though in all new streets for some years past the separate system has been installed, but, pending the completion of this change, connections have been made to the foul-water sewers. The roads are mostly macadamised, therefore a large amount of finely divided matter finds its way into the sewers. *Mixed.*—The domestic sewage is about 3,750,000 gallons per diem, and the trade refuse 2,000,000 gallons. Of the latter there are dense trade liquors to the extent of 500,000 gallons with a large amount of fibre and other impurities from wool-scouring. Effluents are received from eleven dye works, ten wool-sconers and spinners, two fellmongers and one currier. Manufacturers are required to arrest the solids by settlement in small catch-pits, which if not regularly cleaned out (and they are not) must of course discharge their contents, more or less, into the sewer. Plans have to be submitted for all new works, but the effluents may be turned out at any time convenient to the manufacturer. *Subsoil Water.*—About 1,500,000 gallons

of well and subsoil water are included in the daily flow of sewage, the *Dry-weather Flow* thus amounts to 7,250,000 gallons, and the *Storm Flow* to the farm is in wet weather probably over 12,000,000 gallons. *Water Supply.*—Some 19 gallons per head per diem is given as the water supply, and the sources are various gathering grounds in Leicestershire. [It will be remembered that Leicester has recently been very short of water, but it is participating in the Derwent Valley scheme, and will in the future have an ample supply.] The *Rainfall* is about 20 in. per annum, and the *Drainage Area* of district sewered 1,970 acres. *Flushing.*—The pipe sewers are cleansed by flushing manholes fitted with quick-lifting peststocks. The *Length of Stay* in the sewers is about one and a quarter hours from the centre of the borough to the pumping station and one hour from the pumps to the settling tanks, the *Distance* being about 2 miles. *Storm Overflows.*—Two sewers, each 6 ft. 9 in. by 4 ft. 6 in., deliver to the storm overflow chamber, whence there is a 5-ft. cast-iron circular sewer to the pumps. This, with a fall of 1 in 600, gives a capacity, when running full, of 5,458 c.f.m. The corporation are required by Act to pump 60 gallons per head per diem, but actually pump more. From the storm overflow chamber a sewer 8 ft. in diameter comes into operation when twice the dry-weather flow is exceeded, this discharges $3\frac{1}{4}$ miles away into the river Soar near Wanlip. There are also seven local storm overflows to the canal and the river Soar, and they come into use when the rainfall exceeds 2 in. in twenty-four hours, or $\frac{1}{2}$ in. in one and a half hours. The grosser solids are taken out of the sewage by *Screens*, with $\frac{3}{4}$ in. spaces. The *Pumps* convey the sewage through two 33-in. cast-iron pipes to a distance of $1\frac{1}{2}$ miles, the rise being 169 ft. 6 in. *Settling Tanks.*—There are two tanks, each 98 ft. 6 in. by 63 ft. $10\frac{3}{4}$ in. by 6 ft. average depth, and one similar but only 63 ft. wide. They are fitted with scum boards 18 in. deep, are worked continuously and are cleaned out once in three weeks. About half of the

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suspended solids is removed from the tanks as sludge and a thick fibrous scum 3 in. to 15 in. deep is formed, particularly in hot weather and in the absence of wind. *Stay in Tanks.*—The total combined capacity of the tanks is 600,000 gallons—i.e., less than 10 per cent of the normal dry-weather flow. The sewage remains, therefore, about two hours in the tanks. The *Screenings* are carted away and sold; the *Sludge* is partly disposed of on the farm and partly sold. The *Analyses*, both chemical and bacteriological, of the sewage will be found at the end of this section compared with those of the effluent and of the stream.

Soil and Subsoil. The *Soil* is of a very clayey nature, 6 in. to 12 in. deep over the greater portion of the farm.

About 25 acres to 30 acres near the Anstey Brook are rather better, having a certain depth of alluvial soil; further, part of the soil has been lightened by plunging in sludge. The soil cracks badly in hot weather. The *Subsoil* is 2 ft. 6 in. to 3 ft. of yellow clay overlying hard boulder clay and Keuper marl. *Under-drainage.*—Agricultural drain pipes have been laid at distances varying from 24 ft. to 99 ft. and at a depth of 4 ft. (two fields, 8 ft. deep), and they are now put in at a depth of 3 ft. They are connected to 4-in. to 6-in. master-drains. *Subsoil Water and Floods.*—There is practically no subsoil water; the one sample referred to in the chemical analysis as regards chlorine was obtained with great difficulty. The farm is situated on the slopes of a hill and is not subject to floods.

The *Mechanical Analysis* shows the following percentage composition of the ignited soil (average of boiled and not boiled samples). The subsoil was not analysed.

MECHANICAL ANALYSIS.

Fine gravel (above 2 mm.) - medium sand (above 0.25 mm.)	...	...	...	...	...	11.065
Sand (0.25 - 0.05 mm.) - silt (0.05 - 0.01 mm.)	...	...	...	...	...	60.985
Dust (0.01 mm. - settling from water within twenty-four hours) - clay (still finer precipitated by dilute nitric acid)	...	...	...	...	...	14.2
Loss on ignition (separate determination)	...	...	...	...	...	12.285
						98.535

The approximate number of particles in 1 gramme was 2,204,335,000, and in 1 c.c. 2,744,416,680.

The *Lime* (parts per 100,000) dissolved by water

in twenty-four hours is for soil 0.073, subsoil 0.017; and dissolved by water saturated with carbonic acid in forty-eight hours, for soil 0.554, subsoil 0.467.

Area, Population, &c. The total area of the farm is 1,699 acres, and of this 1,350 acres are available for sewage treatment.

The average area under irrigation at one time is 337 acres; the population served is 197,000, which works out at 146 persons per irrigable acre, or 555 persons per acre for the average area irrigated. The normal dry-weather flow is 36.8 gallons per head per diem. The amount treated per acre for twenty-four hours at the normal rate of flow is 21,500 gallons on the average area irrigated, equal to 5,370 gallons on the whole irrigable area.

Treatment and Cropping. With regard to the *Treatment* of the sewage, I cannot do better than quote the evidence of the borough engineer and surveyor, Mr. E. George Mawbey, M.INST.C.E., given to the Royal Commission on March 7, 1901:—

“The way we prepared it was this: First of all the ordinary ditches were widened and deepened to serve as the main effluent drains leading to the natural watercourses, and the drain of each field has its own separate outfall, which is brought out on to the surface of the lower field, and arranged so that the foul effluent that always reaches the drains of a clay farm can be treated a second or a third time on other land as may be found necessary to effect a sufficient purification. A surface effluent can always be treated on successive areas until fit to send into the streams—in the old orthodox way of irrigation, that is. The top land which adjoins the sewage carriers is all arable. There are 453 acres of that,

part of which has been broken up from old pasture. The crude sewage is first discharged on to this arable land and finished off on the old pasture or rye

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grass. The lower fields, which were originally arable, have been seeded down, and the total area of the pasture land is 902 acres. By this means the drawbacks of a clay farm are very largely overcome. I should like to say one more word about that. I have had something to do with clay land before, and I have always found that if you do drain it in the ordinary way, as there is only a small depth of humus, you do not get sufficient filtration, and it finds its way down into these drains (not having got its 6 ft. or 7 ft. for filtration) in a foul condition. We expected the same failure at Leicester. It was prophesied that we should fail because of that. Some said: 'Well, you must not drain the land.' Well, we tried that for a little while, and we found that we could not possibly get the horses on. We

it out to the surface of the next field below as quickly as possible and dealing with each field the same; so that the foul effluent which gets into the drain at one field is thrown over the surface of the next, and on the next again, if not fit to send away, and when it is fit to send away we can drop it into any one of these dykes, let it go away through the ordinary natural drains of the land, or bring it on to the surface of the land again, and in that way we achieved a very great success." The hulk of the sewage "was held up within 1 ft., but of course it would gradually permeate through 2 ft. or 3 ft. more, but extremely slowly, not sufficiently." "And then it concentrated itself over the trenches naturally, and there found its way into the drains. Always in hot weather, after rest of the land, we had the

DATES OF VISITS, MEAN TEMPERATURES, RAINFALL, &c.

Dates of Visits.	Mean Temperatures (deg. Fahr.).			Mean daily Rainfall (inches).	Remarks.
	Air.	Sewage.	Effluents.		
1899. November 8-21	44	56	48	·04	—
1900. August 21—September 3	58	62	64	·05	·63 rainfall on August 23rd Experiment
September 10-27	57	63	61	·01	
1901. September 30—October 4	—	64	60	·03	--
1902. February 11-13	—	—	—	·00	Twenty-four hours' sewage samples

have had to wait from twelve to twenty weeks before we could get the horses on to plough after sawaging; we found that we must drain it, and we got over it in this way, but it was after a great deal of study. The farm, fortunately for us, has good slopes, so that pumping the sewage on to the top of the watershed, part of it falls down to one valley and part to another; and the idea I conceived was that, instead of having an arterial system of drains and connected up to the main drains, so that when you put the sewage on to a top field it would pass through only 6 in. to 1 ft. of soil, into the system, which was as good as into the river at once; instead of doing that I have laid a main drain along the bottom of each field to the lowest corner, and taking advantage of the superior slope of the farm, getting

fissures in the clay to deal with, and it used to run through these and get quickly down that way." Owing to the retention on the surface of the land of the solids left in suspension, a very offensive smell arises in hot weather, but as this occurs in the middle of some 1,700 acres and on comparatively high ground no "nuisance" is occasioned thereby. The sewage is usually applied continuously (night and day) for about fourteen days to the same plots. The *Experiment* will be dealt with hereafter. *Cropping*.—The chief crop is rye-grass; mangold wurzels are also grown, and about 20 acres to 30 acres of wheat per annum to provide straw for thatching. At times 1,000 head of cattle are maintained, and the number seldom falls below 500 to 600.

Land Treatment of Sewage.

**Analyses—
Sewage, Effluent
and Stream.**

It should be noted that the sewage was screened and settled. Allowances must be made for evaporation in comparing the effluent with the sewage. The chief *Chemical* results are :—

which must sometimes impose a considerable strain upon such heavy land." (Part II., page 135.) "The Anstey Brook may therefore be regarded as having been, from a chemical point of view, in a fairly satisfactory condition (for a non-drinking-water stream) at the time of Mr. Kershaw's visits to

CHEMICAL ANALYSES (PARTS PER 100,000 BY WEIGHT).			
—	Sewage.*	Effluent. (8-13 samples.)	Stream. (1 sample.)
Total nitrogen	6.53	2.53	0.31
Ammoniacal nitrogen	6.53	1.65	0.055
Total organic nitrogen... ..	1.93	0.45	—
Albuminoid nitrogen	1.14	0.20 = { 83.2 per cent purification } (average)	0.00
Oxygen absorbed 4 hours at 80 deg. Fahr.	16.16	2.50 = { 82.8 per cent purification } (average)	0.47
Nitric and nitrous nitrogen	—	0.51	0.18
Chlorine (in water supply 1.93 and in subsoil water 1.96)	10.08	10.79 (?)	2.30
Incubator test as judged by smell	—	{ 92 per cent passed (13 samples) }	{ Not noted. Sure to be right }
Solids in suspension (hourly samples only)... ..	34.1	—	—
* Approximate averages of three sets of samples drawn in equal quantities per hour for twenty-four hours and of five chance samples.			

"The effluents were either clear, slightly opalescent, or in one or two cases more or less turbid. Their colour was brown or sometimes yellow, and there was always some flocculent matter present, for the most part, no doubt, fragments of weed from the drains, tinged with oxide of iron. Every sample was alkaline, some of them strongly so. When they came to be analysed the smell was quite clean—i.e., usually earthy, though sometimes inclining to a seaweed or fishy odour. In a few samples tested there was much lime and sulphate in solution." (Part II., page 133.)

"The effluents obtained, while not of a high class, are better as regards keeping property than the figures of analysis would lead one to expect. Taking them all over they may be described as moderate. The sewage is no doubt a somewhat difficult one to treat, and the nitrifying area afforded by such a stiff soil and subsoil is necessarily small (relatively). As the slope of the farm, speaking generally, is all that could be wished for allowing the sewage to be treated over a number of plots of ground successively, the conditions in this respect are favourable. But, on the other hand, one must not forget that storm water up to twice the dry-weather flow is treated,

Leicester, if we take the relatively small dilution of effluent by brook water into account." (Part II., page 139.)

The *Bacteriological* figures may be summarised as on following page.

"Considered from the bacteriological point of view, none of the effluents were in a fit state to be turned into a drinking-water stream. The majority were even hardly in a proper condition to be discharged into non-drinking-water rivers. Nevertheless, the fact that some of the effluents were sufficiently pure to be discharged into a non-drinking-water stream, and that a fair number of them, although exception might be taken to them, came within measurable distance of satisfying reasonable standards, encourages the belief that by acquiring an increased area of land the effluents from Leicester sewage farm might be made uniformly fairly good. Whether acquiring a further area of land is practicable or advisable is a separate question, and need not be discussed here. The only contention is that the results were not so uniformly and unmistakably unsatisfactory as to point to the impossibility of obtaining continuously good results with land of the kind available at Leicester." (Part III., page 93.)

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Effluent and Stream Compared.

The ratio of effluent to brook at the time of sampling was 1 to 1. The volume of water in this small brook is sometimes less than that of the combined effluents from the farm in summer. The samples tested varied somewhat, as was to be expected with

In three samples drawn in November the dissolved oxygen averaged fully 5 c.c. per litre—this was evidently due to the lower temperature. None of the other effluents showed more than about 1 c.c. when they came to be analysed, and in a good many of them it was apparently absent altogether. But the

BACTERIOLOGICAL ANALYSES (TOTAL NUMBER OF BACTERIA PER C.C.).			
—	Sewage. (5 samples.)	Effluent.* (9 samples.)	Stream. (1 sample.)
(1) Gelatine at 20 deg. C.	12,220,000	532,777 { 95 per cent } { reduction } { }	540,000
(2) Agar at 37 deg. C.	1,614,000	70,500 { 95 per cent } { reduction } { }	71,000
(3) B. coli or closely allied form (say at least) ...	82,500	11,466 { Varied from } { absent from } { 10000 c.c. to at } { least 100,000 }	1 not 10
(4) B. enteriditis sporogenes (spores—say at least)	550	4 { Varied from } { none in 1 c.c. } { to at least 10 } { but less than } { 100 }	None in 1 c.c.
* Satisfactory (1) 3, (2) 3, (3) 3 and (4) 6 out of 9 effluents in each case.			

such a small flow of water, and they contained appreciable amounts of suspended solids, no doubt from the effluent drain pipes; but, taking the existing circumstances of small dilution into account, the condition of the brook might be regarded as fairly satisfactory from a chemical point of view. The Anstey Brook at the time of the visits to the farm appeared to be in a clean state. The stream has a fairly rapid current in places, with a gravelly bottom and an abundance of weeds and green

copper chloride method for oxygen determination is not at all suitable for brown-coloured effluents like those from Leicester, and the results are doubtless therefore distinctly too low. Of samples of water from the stream one maintained its aeration fairly well (brook low), one had its dissolved oxygen nearly exhausted (brook very low), and one lost very little of its dissolved oxygen (brook normal)—as this was jointed ten days in September it was a severe test.

DISSOLVED OXYGEN (PARTS PER 1,000 = C.C.'S PER LITRE).			
—	Boiled out.	Cuprous Chloride at time of	
		Drawing.	Analysis.
Effluent	4.70—5.73 average 5.22	— — —	0.0—1.5 average 0.55
Stream	— — — average 6.29	— — —	0.8—6.5 „ 4.17
Mixture	5.74—7.99 average 7.07	— — —	5.5—5.8 „ 5.65

growths. Holes occur in places from 3 ft. to 6 ft. deep, and some of these contain fish. The brook had a fair amount of dissolved oxygen, and there was no smell or sewage fungus noticeable. The effluent from another small farm close by runs into the brook below the Leicester outfall.

Nuisance and Difficulties.

The operations attending the removal of the sludge from the settling tanks take some time, and are attended by considerable smell, and this nuisance is accentuated in hot weather; the smell, however, does not reach to a great distance from the

Land Treatment of Sewage.

tanks except in damp foggy weather. The chief difficulty experienced in the working of the farm is the disposal of the sludge, on account of the long time it takes to dry sufficiently to admit of removal, and a large area of land has to remain uncropped in consequence of the necessity for reserving a place for the deposit of some of this sludge. (See also last sentences under "*Treatment.*")

sewage of Belgrave would bring the population per acre up to 154. As the result of numerous experiments, having for their object the clarification of the sewage before its application to land, process No. 7 was recommended. This consisted of a closed detritus tank, clarifying bacteria beds (three fillings a day), and old pasture (one application). The results averaged :—

PERCENTAGE PURIFICATION ON CRUDE SEWAGE (PROCESS No. 7).			
—	Suspended Matters.	Albuminoid Ammonia.	Oxygen absorbed at 80 deg. Fahr. in four hours.
Closed detritus tank	53·5	24·47	22·12
Clarifying bacteria beds	88·8	70·98	71·17
Old pasture	99·12	86·76	91·08

Conclusions. "The sewage (three-quarter domestic, one-quarter trade refuse) is only of moderate nitrogenous strength, but contains a considerable amount of oxidizable matter. For a combined surface irrigation and filtration farm Leicester was treating a fairly large volume of sewage per acre of the 'working' daily irrigable area, but not a large volume per acre of the total irrigable area. As regards the organic matter, it was treating about one-half that of Nottingham. The soil and subsoil (stiff clayey soil overlying dense clay) are certainly not well suited for purifying a large volume of sewage. The sewerage system is partially separate. The farm does not deal with very much storm water. We think that 21,500 gallons per acre per twenty-four hours (5,370 gallons per acre of the total irrigable area per twenty-four hours) is rather too large a volume of a mixed sewage of moderate strength to be treated by screening, settling, and surface irrigation (with some filtration) on soil of the above nature." (Part I., p. 89.)

LATER WORK.

The population at the commencement of work, September, 1890, on the Beaumont Leys farm was 114 persons to the acre, though, it should be noted, many houses were not provided with water-closets. In 1900 Mr. Mawhey presented to the Corporation of Leicester a report from which the following information is largely derived. The sewage from no less than 145 persons per acre together with the dense trade water of the borough is now being treated. The proposed addition of the

The suspended matters in the crude sewage during the thirty-three weeks of the experiment averaged 43·7 grains per gallon, the albuminoid ammonia 1·182 grains per gallon, and the oxygen absorbed 7·442 grains per gallon. [62·43, 1·7 and 10·63 parts per 100,000.] Alternative schemes for the treatment of the sewage by this process were prepared, and the one recommended was commenced in January, 1905. The works comprise (a) seven detritus tanks of a total capacity of 1,400,000 gallons, or rather more than one-sixth of the present dry-weather flow, (b) eighteen clarifying bacteria beds, each 350 ft. by 83 ft. (total about twelve acres), and with filtering material of an average depth of 4 ft. 4 in.; the water capacity, calculated at fifty gallons per cubic yard, being about 4,194,600 gallons; and fitted with automatic inlet feeds and timed discharges; (c) an effluent pumping station where the clarified sewage will be sent through two 34-in. rising mains into the existing main carrier, and (d) a sludge rising main which will discharge on to the land at various points. Some of the general conclusions of the report before referred to are :—

"Having regard to the facilities afforded and success achieved by the peculiar and perhaps almost unique manner in which our heavy clay land has been prepared, drained, and managed, it does not appear from the experiments that any improvement in final purification can be obtained by an entire system of bacteria treatment, as opposed to a system of clarification by detritus tanks and bacterial filters followed by final purification on old pasture or rye grass. The experiments do, however, show that our sewage could be purified without treatment

Leicester.

on land, but in the land we have a well proved system which should not be lightly abandoned, and especially so considering that on the various works at Beaumont Leys and in the preparation of this land nearly £59,000 have been expended, as well as £12,922 for the rising mains to deliver the sewage there. With respect to the proposal to purchase the Beaumont Leys sewage farm, having due regard to the proved efficiency of the land, as now laid out, for final purification, and the cost

which would be involved in constructing a sufficient area of second and third contact bacteria beds in the near future to take the place of the land used for irrigation, I am of opinion that it is desirable to endeavour to purchase the 1,275 acres of land now leased until the 25th March, 1916, from Sir Robert Tempest-Tempest, Bart." This has since been done, and the works referred to above were commenced in January, 1905—it is hoped that they will be completed this year.

NOTTINGHAM.

HISTORY.

The farm was started about the year 1880, and has from time to time been extended to meet the needs of a growing population and to allow for the inclusion of the other places hereinafter referred to.

In the evidence given to the Commission on May 8, 1901, by the Hon. T. H. W. Pelham, Assistant Secretary to the Board of Trade, in charge of the Fisheries and Harbours Department, reference is made to the pollution of salmon rivers and specimen cases are quoted in which the Board of Trade have communicated with the Local Government Board. In July, 1896, the conservators called attention to the serious destruction of fish in the river Trent, "thousands of fish of all kinds for many miles" being killed. I have been informed that this took place 3 or 4 miles above the outfall of the effluent from the sewage farm. A representation was made to the Local Government Board in the matter, and again in 1898 in connection with an application by the corporation for a Provisional Order to enable them to acquire additional land for a sewage farm. In 1899 and 1901 the Local Government Board sanctioned loans for the sewerage scheme on condition that the town council would not at any time allow unpurified sewage to pass into the river.

REPORTS TO THE ROYAL COMMISSION.

Conservancy.—The number of water-closets connected to the sewerage system is 10,850; there are also 40,550 tub-closets, 2,334 waste water-closets or slop-closets and 300 midden privies. In the case of the tub-closets the greater part of the urine is emptied down the backyard gullies and goes to the sewers. *Combined.*—All storm and surface water goes to the foul-water sewers. Many of the streets are paved with stone setts—a fact that probably, partly, accounts for the comparative absence of sludge on the farm. *Mixed.*—Approximately three-sevenths of the total flow consists of refuse from bleach, dye and bone works, wool-scouring, breweries,

laundries and fellmongers; the bleach and dye effluents preponderate. The refuse is not treated by the manufacturers previously to leaving the works. *Subsoil Water.*—Owing to the reconstruction of the sewers there is little subsoil leakage. The *Dry-weather Flow* is about 7,000,000 gallons per diem. *Storm Flow.*—About 10,000,000 gallons is the limit that can be treated on the farm, this being the utmost that the carriers can take. The *Water Supply* is about 20 gallons per day in summer and about 16½ gallons in winter, obtained from deep wells in the new red sandstone. The average annual *Rainfall* for the past thirty-two years is 25 in. The area of the city is 10,935 acres, but no mention is made of the *Drainage Area*. *Flushing.*—In the low-lying districts the sewers are flushed systematically by means of movable flushing tanks. *Stay in Sewers.*—The time taken by the sewage to reach the pumping station from the centre of the city is about one hour, and from the pumping station to the farm about two hours, the *Distance* to the farm from the pumping station being about 3½ miles, equals 5 miles from the centre of the city to the farm. *Sewer Capacity.*—The size of the main outfall sewer to the farm is 5 ft. 3 in. by 5 ft., laid at a gradient of 1 in 2,455, and having a capacity when running full of 2,698 c.f.m. There are four *Storm Overflows*, one discharging into the river Leen and three into the river Trent. They come into operation when the rainfall exceeds ¼ in. in twenty-four hours. *Screens.*—About two-thirds (say, 4,500,000 gallons) of the sewage is screened by upright bars set 1 in. apart—the screen is intended to protect the pumps. The sewage gravitating to the farm is not screened in any way. The *Pumps* deal with two-thirds of the sewage, lift it about 15 ft., and force it to a chamber on the outfall sewer ½ mile from the pumping station. The rest of the sewage flows to this chamber by gravitation, and the whole of the sewage then reaches the farm in like manner. About six cart-loads per week of *Screenings* are dealt with by the destructor. The *Analyses*, both chemical and

Land Treatment of Sewage.

bacteriological, of the sewage will be found at the end of this section compared with those of the effluent and of the stream.

The *Soil* on the farm varies somewhat. For the most part there is from 7 in. to 15 in. surface soil of a light, porous, sandy loam, interspersed

main drains are 132 ft. apart and the feeders 66 ft. *Subsoil Water and Floods.*—There is practically no subsoil water on the farm at the depth at which the pipes are laid. The irrigation land is not liable to floods.

The *Mechanical Analysis* shows the following percentage composition of the ignited soil and subsoil :—

MECHANICAL ANALYSIS.										Soil.	Subsoil.
—										—	25·47
Gravel (above 8 mm.)										23·01	28·68
Fine gravel (above 2 mm.)—medium sand (above 0·25 mm.)										59·66	41·68
Sand (0·25–0·05 mm.)—silt (0·05–0·01 mm.)										10·33	2·23
Dust (0·01 mm.—settling from water within twenty-four hours)—clay (still finer precipitated by dilute nitric acid)										6·16	1·28
Loss on ignition (separate determination)										99·16	99·34

with and overlying (*Subsoil*) river valley gravel and sand. It is admirably adapted for sewage filtration. *Under-drainage.*—The entire farm is under-drained by 4-in. agricultural pipe feeders, laid herring-bone, and 7-in. to 12-in. socketted pipe mains, which in turn are connected, where necessary, into larger pipe mains. The feeder drains are laid from

The approximate number of particles in 1 gramme is for soil 819,191,490, subsoil 290,000,370; and in 1 c.c. for soil 1,181,291,470, subsoil 514,162,730.

The *Lime* (parts per 100,000) dissolved by water in twenty-four hours is for soil 0·009, subsoil 0·017; and dissolved by water saturated with carbonic acid in forty-eight hours, for soil 0·060, subsoil 0·070.

DATES OF VISITS, MEAN TEMPERATURES, RAINFALL, &c.					
Dates of Visits.	Mean Temperatures (deg. Fabr.).			Mean daily Rainfall (inches).	Remarks.
	Air.	Sewage.	Effluents.		
1899. December 5-21	34	59	49	·03	{ 24 rainfall on December 5th. Snow on two days. There were several very severe frosts and the lowest reading registered was 10
1900. July 23—August 6	63	65	53	·19	
1901. September 23-27	—	68	56	·00	{ 1·25 rainfall on August 6th, '54 on July 27th, and over '20 on five other days
1902. February 4-6	—	—	—	—	
					Twenty-four hours' sewage samples

4 ft. 6 in. to 7 ft. 6 in. deep. The main drains are laid from 6 ft. to 10 ft. deep. Upon an area of 120 acres ("closely drained area") the main drains are laid at a distance of 66 ft. and the 4-in. feeders 33 ft. apart. On the remainder of the farm the

Acreage, Population, &c. The total area of the farm is 907 acres, and of this 651 acres are available for sewage treatment. The average area under irrigation at one time is 300 acres; the population served is 258,584

Nottingham.

(Nottingham 239,384, Arnold 10,000, and Carlton 9,200), which works out at 397 persons per irrigable acre, or 862 persons per acre for the average area irrigated. The normal dry-weather flow is 27 gallons per head per diem. The amount treated per acre for twenty-four hours at the normal rate of flow is 23,300 gallons on the average area irrigated, equal to 10,750 gallons on the whole irrigable area.

Treatment and Cropping.

Treatment.—The method of irrigation is as follows: About 300 acres are used per twenty-four hours. The total, broadly speaking, is made up of (a) 250 acres of land, which are used on the twelve-hours' system about to be described, and (b) about 50 acres of the 120 acres referred to previously as

a slightly longer period, or the sewage might be run on both day and night for the remainder of the time. *Cropping.*—The "closely drained area" is not cropped as a rule and is kept as frequently ploughed as possible. The crops grown on the farm are mangolds, rye-grass, kohlrabi, thousand-headed kale, ox and market cabbages, swedes, potatoes, wheat, oats, barley, and clover. Rye grass, mangolds and cabbage are the chief crops. A large herd of dairy cattle is kept and the milk, &c., is sold.

Analyses—Sewage, Effluent and Stream.

The sewage is rather strong and decidedly alkaline, but owing to its long journey it arrives at the farm in a well broken-up condition. The chief *Chemical* results are:—

CHEMICAL ANALYSES (PARTS PER 100,000 BY WEIGHT).			
	Sewage.*	Effluent. (13 samples.)	Stream. (1 sample.)
Total nitrogen	6.96	2.27	0.38
Ammoniacal nitrogen	3.95	0.13	0.06
Total organic nitrogen	2.73†	—	—
Albuminoid nitrogen	1.63	0.03 { 98.5 per cent purification (average) }	0.055
Oxygen absorbed, 4 hours at 80 deg. Fahr. ...	20.03	0.19 { 99 per cent purification (average) }	1.325
Nitric and nitrous nitrogen	—	2.06 { 1.24 — 1.71 in 4 later samples }	0.245
Chlorine (in water supply 1.06)	15.21	11.86 (?)	4.25
Incubator test as judged by smell	—	— { 100 per cent passed (17 samples) }	Sweet
Solids in suspension (hourly samples only) ...	51.9‡	—	—

* Approximate average of three sets of samples drawn in equal quantities per hour for twenty-four hours and of four chance samples.
† Probably too low; not to be relied upon.
‡ Higher than normal in all probability—rain washed sewers when sample No. 406 drawn (79.2).

the "closely drained area," which are employed for increases in the sewage flow. (a). The sewage is run continuously in periods of twelve hours on to each half (125 acres) alternately of the 250 acres above mentioned. Thus each half (125 acres) is allowed a resting period of twelve hours. About 50 acres of the "closely drained area" are sewaged continuously until the land shows signs of becoming over-sewaged. When this takes place a portion of the remaining 70 acres is brought into use. Approximately the same land is sewaged for about one month before the sewage is taken off. If, however, at the end of that time the same area was continuing to produce a satisfactory effluent it might be sewaged for

"These are all *percolation* effluents . . . All the effluents were of wonderful quality, the best of them approaching in fact to drinking waters. They were uniformly clear, colourless, and without smell . . . The last samples examined . . . contained quite appreciable amounts of red-brown flocculent sediment—no doubt vegetable growth from the drain pipes, coated with hydroxide of iron. The effluents were all alkaline in reaction, and contained (relatively) a great deal of lime and much sulphate in solution." (Part II., page 200.) "The Nottingham farm treats on an excellent loamy soil and gravelly subsoil, most of the land being cropped, a medium volume of a rather strong sewage containing 40 per

Land Treatment of Sewage.

cent of trade refuse . . . The result is an effluent of altogether exceptional quality, clear and sparkling, and approaching in the best samples within measurable distance, from a chemical point of view, of a drinking water . . . There is only one other point to which attention may be drawn before closing—*viz.*, the rapidity with which the soil of the Nottingham farm recovers itself after being over-sewaged . . . I trust that in this report the great purity of the Nottingham farm effluents, from a chemical point of view, has not been dwelt upon too much ; but one feels that too great stress can hardly be laid upon this, because it shows what admirable results can be obtained from good land under good management.” (Part II., pages 201 and 202.)

The *Bacteriological* figures may be summarised as follows :—

for potable purposes. None of the other sewage farms under investigation yielded effluents which approached the degree of biological purification effected by the land treatment in the case of Nottingham sewage farm.” (Part III., page 131.)

Effluent and Stream Compared.

The ratio of farm effluent to river water is normally about 1 to 160, but the variations of volume are great—the minimum ratio is 1 to 60. It may be mentioned that the Trent receives the sewage from most of the populous villages on the banks except Arnold, Carlton and Beeston ; the sewage from Radcliffe flows untreated into the Trent a short distance above the Nottingham sewage farm, the ditch conveying the sewage to the river being (July, 1900) in a filthy condition. The river

BACTERIOLOGICAL ANALYSES (TOTAL NUMBER OF BACTERIA PER C.C.).			
—	Sewage. (2-3 samples.)	Effluent.* (8-15 samples.)	Stream. (1 sample.)
(1) Gelatine at 20 deg. C.	23,350,000	304,770 { 98 per cent reduction	—
(2) Agar at 37 deg. C.	5,146,666	101,157 { 98 per cent reduction	3,300
(3) B. coli or closely allied forms (say at least)	550,000	851 { Varied from absent from 100 c.c. to at least 10,000 but less than 100,000	100 not 1,000
(4) B. enteriditis sporogenes (spores—say at least)	400	1 { Varied from none in 100 c.c. to at least 10 but less than 100	{ At least 1 but less than 10
* Satisfactory (1) 7 out of 8, (2) 11 out of 15, (3) 11 out of 12 (absent from 7), and (4) 14 out of 15 effluents (absent from 13).			

“The results as a whole were unquestionably very good, and some of the effluents might, on superficial observation and without a knowledge of their source, have been classed as pure drinking water. But, as has already been pointed out, evidence was not lacking that the intrinsic biological qualities of the sewage were not materially altered by the land treatment but only ‘masked’ to a remarkable extent. If this supposition be correct . . . immunity from danger to health arising from the discharge of such effluents into drinking-water streams would be relative, not absolute. But whether or no question arises as to the propriety of discharging effluents possessed of the biological qualities observed in the case of the Nottingham effluents into a drinking-water stream, there can be no doubt as to the fitness of these effluents to discharge into a river not used

below the effluent outfalls at the time of visiting the farm was apparently in good condition, and no sewage weed was seen. In the months of July and August, 1900, the water of the Trent was not at all of high quality, though there was nothing offensive about it ; it contained for a river water a large proportion of oxidisable matter, and usually a considerable quantity of solids in suspension. The volume of effluent as compared with that of the river is very small, but, so far as it goes, the effluent must exercise an oxidising effect on the water of the river.

The first two series of effluents (drawn in December, 1899, and in July and August, 1900) were very well aerated for percolation effluents (probably aerated in the drains), containing as they did, when analysed, an average of about 5 c.c. dissolved oxygen per litre for thirteen samples ; and of the two

Nottingham.

duplicates which were jointed, the oxygen in No. 111 was reduced from 3.0 c.c. to 1.6 c.c. per litre in ten days at atmospheric summer temperature, while that in No. 121 underwent no reduction in nine days under like conditions, remaining at about 6 c.c. per litre. This is, of course, very remarkable for an effluent, and places it, in this respect, among drinking waters. The last four samples, drawn in September, 1901, were (like No. 111) not so highly aerated as the others when they reached the laboratory, containing an average of about 2.5 c.c. dissolved oxygen; but in every case the duplicates retained something like 1 c.c. of this after being jointed and incubated at 26.7 deg. C. (80 deg. Fabr.) for a fortnight. For a non-drinking-water stream there was nothing offensive about the water, but it was not of high quality; not nearly so good, in fact, as the Nottingham sewage farm effluents. The jointed samples kept for a week to a fortnight in warm summer weather retained a little dissolved oxygen (No. 117 as much as 4 c.c.).

Conclusions. "The sewage (four-seventh domestic, three-sevenths trade refuse) is strong. For a filtration

farm Nottingham was not treating a large volume of sewage, either per acre of the 'working' daily irrigable area, or per acre of the total irrigable area, more especially if the nature and effective internal purifying surface of the soil and subsoil are taken into consideration; but it was actually treating a large quantity of organic matter. The sewerage system is combined, but the farm deals with very little of the storm water. There can be no doubt that 23,300 gallons per acre per twenty-four hours (10,750 gallons per acre of the total irrigable area per twenty-four hours) is not too large a volume of even a strong sewage to be treated by screening (partial) and filtration through about 6 ft. of soil and subsoil (sandy loam overlying gravel and sand) of the nature of that found at Nottingham. It is pleasant to be able to call attention to the fact of a sewage farm working well within its

DISSOLVED OXYGEN (PARTS PER 1,000 = C.C.'S PER LITRE).						
—				Boiled out.		
				Cuprous Chloride at time of		
				Drawing.		Analysis.
Effluent ...	...	...	...	4.55-5.76 average 5.25		2.2-6.1 average 4.1
Stream ...	...	...	...	— — —		1.0-4.5 „ 3.17
Mixture ...	...	...	...	— — —		4.7-4.8 „ 4.75

Nuisance and Difficulties.

There was no noticeable smell arising from the sewage operations. Occasionally, in hot weather, the stirring up of the sewage in passing under the road syphons causes a slight smell, but only in the immediate vicinity. The available area is barely sufficient for the present volume of sewage, and the former will be greatly increased shortly, as the farm is soon to be enlarged to more than double. The carriers are worked to their utmost capacity, frequently overflowing at the period of maximum flow, and consequently can only deal with a small amount of storm water in addition to the sewage proper.

limits of purifying power, and as a result yielding effluents of a highly satisfactory character." (Part I., page 93.)

LATER WORK.

At the time Mr. Kershaw's report was made an extension of the farm to a total area of 1,946 acres was in progress. The additional area is now being brought into use, and the sewage is fed to the new land by a series of syphons ending in concrete chambers. The irrigable area is increased by 515 acres, making a total of 1,166 acres for sewage treatment.



RUGBY (HIGH LEVEL).*

HISTORY.

A reference to this sewage farm occurs in the Rivers Pollution Commission First Report, Vol. I., pages 79 and 80 (1870):—

“At Rugby—a town of more than 8,000 inhabitants—the board of health have taken a lease of 65 acres of land for a term of thirty-one years, at a rental which, with rates and taxes, amounts to £4 10s. per acre; and, confident in the powers of their somewhat gravelly soil (lying upon a clay subsoil) to cleanse their town drainage and so convert it into valuable produce, they have laid out nearly £5,000 on the works required for the distribution of the sewage over it . . . The quantity of sewage at command is about 900 tons a day, or nearly 4,000 tons per annum for every acre of the farm. The land has been in hand for only one year, and much of it was sown with Italian rye grass for the first time in the spring of 1869, so that the best results can

which it had passed 150 yds. down the slope, thence it flowed along a surface channel about 300 yds. to another acre of Italian rye grass; and No. 3 was taken at the foot of this grass plot, about 80 yds. from the carrier which supplied it.”

REPORTS TO THE ROYAL COMMISSION.

Separate or Combined.—The **The Sewage.** separate system is used in parts of the town, but all the water from back portions of roofs and yards drains to the foul-water sewers. The sewage is *Domestic* with the exception of some oil from engine works. *Subsoil Water.*—The sewers on the whole are in fair condition; a large amount of subsoil water, however, is admitted to some of the older sewers where clay joints were used instead of cement. The average *Dry-weather Flow* is about 300,000 gallons per twenty-four hours. The *Water Supply* is 26·5 gal-

SEWAGE AND EFFLUENTS (PARTS PER 100,000).

	Total Solid Matters in Solution.	Organic Nitrogen.	Ammonia.	Nitrogen as Nitrates and Nitrites.	Total Combined Nitrogen.	Chlorine.	Suspended Matters.		
							Mineral.	Organic.	Total.
(1) Sewage	52·60	2·322	7·276	·000	8·314	8·25	3·48	8·96	12·44
(2) First field	55·70	·506	2·772	·000	2·789	10·20	·72	·28	1·00
(3) Second field	68·20	·164	·420	·000	·510	10·50	·88	·36	1·24

hardly have been yet realised . . . A considerable portion had been let at £10 an acre . . . In illustration of the cleansing power of land and plant at Rugby, three samples taken about mid-day July 13 (1869) have been analysed: No. 1 was raw sewage taken from the hydrant as it poured over the top of the farm; No. 2 was the same sewage taken at the foot of $1\frac{1}{2}$ acres of land in Italian rye grass over

*NOTE.—There are two sewage farms at Rugby. The one described deals with the sewage from the N.-W. and S.-W. parts, and has itself both high-level and low-level tanks.

lons per head, and is obtained partly from the river Avon and partly from gathering grounds and wells at Moreton and Bilton. The average annual *Rainfall* from 1855 to 1897 was 25·62; for the year 1900 the rainfall was 30·68 in. *Flushing.*—The gradients are generally self-cleansing; where necessary the sewers are flushed by hose and by flushing penstocks in the manholes. The Rugby School baths discharge about 53,000 gallons of water. *Stay in Sewers.*—The sewage

Land Treatment of Sewage.

takes about one and a half hours to reach the tanks from the town, the *Distance* being about 1 mile. *Sewer Capacity*.—A portion of the sewage is brought to one set of settling tanks by a 36-in. circular brick culvert, with a gradient of 1 in 718, and the remainder by a 12-in. syphon, 1,000 yds. long, to the settling tanks on the farm. Whatever sewage the 12-in. syphon will not take passes by an 18-in. pipe to the low-level tanks, and thence all goes on to the farm. There is one *Storm Overflow*, but it is not recorded that it has come into use within recent years. *Chemical Treatment*.—The sewage is treated before entering the tanks with alumino-ferric, lime and sulphate of iron; alumino-ferric alone being used at night. At the low-level tanks about 144 gallons each of lime and sulphate of iron solutions are used during the twelve hours and two blocks of alumino-ferric, or about 1 cwt. per twenty-four hours. The lime and copperas were run into the sewage from tubs, and the amounts varied considerably. The alumino-ferric was suspended in an iron cage in the sewage channel, above the junction of that channel with the tanks. A large quantity of oil occasionally goes into these tanks and was found very injurious to the rye grass on the farm. It is now skimmed off twice a day from the surface of the tanks, but is not utilised in any way. The same chemicals are used at the high-level tanks. The *Screens* at the low-level tanks are

the continuous system, one at a time for a normal flow but both for a storm, and are cleaned out once a week. The discharge from the Rugby School baths causes a large rush of water through the high-level tanks and disturbs the sludge. The *Sludge* (about 12 tons, wet, per week) is used by the tenant of the farm as a top dressing for grass land elsewhere. The *Analyses*, both chemical and bacteriological, of the sewage will be found at the end of this section compared with those of the effluent and of the stream.

Soil and Subsoil.

The *Soil* has a depth of about 10 in. of clay. The *Subsoil* is yellow clay, which forms a belt about 5 ft. to 6 ft. deep above the lias. Some of the land cracks beneath the surface in hot weather. Pot-holes of gravel occur in places. *Under-drainage*.—The farm is under-drained with 2-in. socketted pipes, laid herring-bone fashion, 66 ft. apart at a depth of 3 ft. 9 in., and connected to 4-in. and 6-in. butt main drains. *Subsoil Water and Floods*.—There is not much subsoil water on the farm now. Formerly there was a large quantity in the pot-holes of gravel, but drains have now been laid to these and the water has a free outflow. The irrigable land is not liable to floods.

The *Mechanical Analysis* shows the following percentage composition of the ignited soil. The subsoil was not analysed.

MECHANICAL ANALYSIS.									
Fine gravel (above 2 mm.)—medium sand (above 0.25 mm.)	...	...	...	...	...	...	...	...	7.30
Sand (0.25–0.05 mm.)—silt (0.05–0.01 mm.)	...	...	...	...	...	...	...	...	57.79
Dust (0.01 mm. — settling from water within twenty-four hours) — clay (still finer precipitated by dilute nitric acid)	...	...	...	...	...	...	...	...	24.75
Loss on ignition (separate determination)	...	...	...	...	...	...	...	...	9.24
									99.08

of wood with $\frac{7}{8}$ in. holes, 3 in. apart each way. The high-level screens are made of iron bars with $\frac{3}{4}$ -in. spaces. *Settling Tanks*.—The low-level tanks are in duplicate, 87 ft. 6 in. by 25 ft. by 3 ft. 6 in. average depth, with a combined capacity of about 95,000 gallons, and they are usually worked together on the continuous system and are cleaned out about once a fortnight, the sludge being drawn off by chain pumps into sludge bays adjoining the tanks. The high-level tanks are also in duplicate, 65 ft. by 15 ft. by 2 ft. average depth, having a capacity of about 12,000 gallons each. These tanks are used on

The approximate number of particles in 1 gramme was 3,207,341,170, and in 1 c.c. 5,384,971,060.

The *Lime* (parts per 100,000) dissolved by water in twenty-four hours is for soil 0.051, subsoil 0.071; and dissolved by water saturated with carbonic acid in forty-eight hours, for soil 0.482, subsoil 0.969.

Acreage, Population, &c.

The total area of the farm is 40 acres, and of this 35 acres are available for sewage treatment. The average area under irrigation at one time is 7 acres; the population served is 6,000, which works

Rugby (High Level).

out at 171 persons per irrigable acre or 855 persons per acre for the average area irrigated. The normal dry-weather flow is 50 gallons per head per diem. The amount treated per acre for twenty-four hours

one field. The farm has rather a steep slope towards the river, and the high-level sewage as a rule is treated twice and then mixes with the low-level sewage, which comes out about half way down the

DATES OF VISITS, MEAN TEMPERATURES, RAINFALL, &c.					
Dates of Visits.	Mean Temperatures (deg. Fahr.).			Mean daily Rainfall (inches).	Remarks.
	Air.	Sewage.	Effluents.		
1900. June 19—July 9	57	57	62	·06	{ ·47 rainfall on June 25th and ·40 on June 24th
1901. February 18—March 14	40	45	41	·05	{ ·30 rainfall on March 3rd. Snow on February 18th
1902. February 18-20	—	—	—	—	Twenty-four hours' sewage samples

at the normal rate of flow is 42,800 gallons on the average area irrigated, equal to 8,500 gallons on the whole irrigable area.

Treatment and Cropping. *Treatment.*—The chemical treatment has already been referred to. The settlement effected by the tanks is very small, and the sewage on leaving them

farm. The resulting mixture is once treated. The sewage is run on the same area of land continuously, day and night, for periods varying from three to seven days, according to circumstances. Chemical treatment was suspended for a time shortly after the first visit to the farm, only being used during the hot weather to lessen smell. *Cropping.*—The

CHEMICAL ANALYSES (PARTS PER 100,000 BY WEIGHT.)			
—	Sewage.*	Effluent. (16-19 samples.)	Stream. (2 samples.)
Total nitrogen	9·87	2·31	0·355
Ammoniacal nitrogen	7·03	1·62	0·03
Total organic nitrogen	2·74	—	—
Albuminoid nitrogen	1·55	0·18 { 88·3 per cent purification (average) }	0·035
Oxygen absorbed 4 hours at 80 deg. Fahr. ...	15·94	1·41 { 91·1 per cent purification (average) }	1·46
Nitric and nitrous nitrogen	—	0·52	0·27
Chlorine (in water supply 2·30)... ..	11·22	8·64 (?)	2·47
Incubator test as judged by smell	—	— { 75 per cent passed (20 samples) }	Sweet
Solids in suspension (hourly samples only) ...	47·30	—	—

* Approximate averages of three sets of samples (screened and settled) drawn in equal quantities per hour for twenty-four hours and of eight chance samples (3 screened and precipitated, 1 screened and settled, and 4 crude).

is distributed over the farm by earthen carriers. These are very faulty, and the sluices are also in disrepair. Crude sewage is occasionally applied to

crops grown on the farm are rye grass, mangolds, cabbages, oats and wheat, and they are disposed of by the tenant.

Land Treatment of Sewage.

Analyses— Sewage, Effluent and Stream.

The sewage is rather strong and the samples throughout were alkaline, some of them very decidedly alkaline. The sewage arrives at the farm in a fairly fresh condition and not well broken up. It should be noted that the sewage is chemically treated. The chief *Chemical* results are given on preceding page.

"One of the effluents was colourless, but most of them had a faint yellow to brownish tinge, the colour being due to organic matter. They contained but little flocculent suspended solids; in solution there was much lime and much sulphate. The smell, when the effluents came to be analysed, was usually earthy or a mixture of fishy and earthy, and the reaction was alkaline." (Part II., page 222.) "For a farm which must depend mainly upon surface

by the filtration that takes place through them." (Part II., page 224.)

The *Bacteriological* figures may be summarised as below.

"It is certain that none of the effluents were in a fit state to be turned into a drinking-water stream, and the majority of them could not be considered as altogether satisfactory for discharge even into non-drinking-water rivers. But the fact that some of the effluents were so pure (relatively speaking)* suggests that land of the kind available at Rugby, if it is not overworked, is not incapable of yielding a uniformly good effluent; if, in short, the area of land available for irrigation purposes is in proper proportion to the amount of sewage to be treated. In conclusion, the *majority* of the effluents may be said either to have passed or have come within

BACTERIOLOGICAL ANALYSES (TOTAL NUMBER OF BACTERIA PER C.C.).				
	Sewage.* (8 samples.)	Effluent.† (15 samples.)		Stream. (1 sample.)
(1) Gelatine at 20 deg. C.	24,381,250	637,133	{ 97 per cent reduction }	156,000
(2) Agar at 37 deg. C.	3,304,375	81,526	{ 97 per cent reduction }	7,100
(3) B. coli or closely allied forms (say at least)	77,500	1,881	{ Varied from none in 1 c.c. to at least 10,000 }	At least 100
(4) B. enteriditis sporogenes (spores—say at least)	775	19	{ Varied from none in 1 c.c. to at least 100 but less than 1,000 }	Negative 10 c.c.
* 4 crude, 1 chemically precipitated, 2 screened, settled and precipitated, and 1 settled sewage. † Satisfactory 1 (4), (2) 7, (3) 5 and (4) 5 out of 15 effluents in each case.				

irrigation over a stiff soil, the Rugby high-level farm treats a very large volume of a strong sewage . . . Although the results obtained from the examination of the second-field effluents at Rugby are in several respects contradictory, it will be seen that the farm is capable of producing a fair effluent of very even composition in spring; but as regards summer, if our (comparatively few) summer samples can be taken as a general criterion of the working of the farm during that season, the area of land which is allowed for sewage then must be smaller than at other times of the year, for it was obviously insufficient. The mechanical analysis of the surface soil showed it to be more of a clay than it was originally thought to be; but the gravel "pockets" which occur in the clay subsoil no doubt to some extent assist the purification of the sewage

measurable distance of passing the standards provisionally suggested. Therefore with justice it cannot be contended that a heavy loam over stiff clay is wholly unsuited for sewage purification purposes. Percentage, as opposed to actual purification, is misleading, but the remarkable percentage improvement in the effluents as compared with the sewage is worth noting; although it must be admitted that the actual results were not altogether satisfactory." (Part III., page 148.)

Effluent and Stream Compared. The volume of effluent to river water normally is 1 to 30. (Part IV.). [Normal ratio of farm effluent to river water, 1 to 20; ratio at second time

* "For example, seven out of fifteen effluents contained less than 10,000 microbes per c.c. (agar at 37 deg. C.). The average number in these samples was less than one-half the standard limit of 10,000 per c.c."

Rugby (High Level).

of sampling, 1 to 30. (Part I.)] The water of this river was on the whole in fair condition chemically at the time of our observations, but in summer the large amount of oxidisable matter in one of the samples drawn above the effluent outfall showed that there was at the time some polluting liquid—not from the high-level farm—entering the river. The volume of river water to effluent is again rather large here. There was no sign of any nuisance from the farm. When the effluents were analysed the dissolved oxygen in the five summer samples from chemically precipitated sewage was practically nil. In No. 106, on the other hand (the summer sample of effluent from sewage not chemically treated), the dissolved oxygen was very high, although there was no reserve of nitrate. (These oxygens were boiled out.) In the spring samples the dissolved oxygen was only moderate in amount (from 1 to 4 c.c.), but it did not appear to be taken up at all rapidly between the time of drawing and the time of analysis—a very good sign. (These effluents being more or less coloured, however, would tend to make the readings of the copper chloride tubes too low.) Speaking generally, so far as non-putrescibility was concerned, no fault could be found with the river water, and, moreover, the samples maintained their aeration well upon incubation.

Conclusions. “The sewage (mainly domestic) is distinctly strong, although not quite so strong as the sewage at Aldershot Camp and Nottingham. For a combined surface irrigation and filtration farm Rugby was treating a large volume of sewage, more especially per acre of the ‘working’ daily irrigable area, but also per acre of the total irrigable area. The sewage being strong, the farm was therefore treating in the aggregate a large quantity of organic matter—namely, about one-half the total amount which Cambridge treats. The soil and subsoil (heavy loam overlying stiff clay with ‘gravel’ pockets) is certainly not of an ideal kind for purifying a large volume of sewage. It is advisable, however, to call attention here to the method of treatment followed at Rugby—namely, the mixing of one volume of effluent from a larger plot of ground with an equal volume of sewage, and the passing of that mixture over a second smaller plot. The sewerage system is partially separate, but a large proportion of the storm water is treated on the farm. We consider that 42,800 gallons per acre per twenty-four hours (8,500 gallons per acre of the total irrigable area per twenty-four hours) is too large a volume of a strong sewage to be treated by screening, settling and surface irrigation (with some filtration) on soil of the above nature.” (Part I., page 95.)

DISSOLVED OXYGEN (PARTS PER 1,000 = C.C'S. PER LITRE).							
—				Boiled out.	Cuprous Chloride at time of		
					Drawing.	Analysis.	
Effluent ...	...	...	...	0.05—7.15 average 1.50	2.5—4.5 average 3.82	0.0—3.725 average 2.64	
Stream ...	...	...	...	— — 4.04	— — 6.5	— — 6.7	
Mixture...	...	...	...	5.01—5.64 „ 5.33	6.25—8.0 „ 7.13	— — 1.85	

Nuisance and Difficulties. In hot, close weather considerable nuisance arises from the cleaning out of the tanks and also from the carriers. The latter is caused by matter derived from the sewage being held back by the inequalities in the carriers and putrefying. The chief difficulties in working the farm are the want of land for moving the sewage, as the wheat and oats cannot be sewaged and occupy valuable space.

LATER WORK.

The area available for sewage disposal has been diminished by extensive excavations for the adjoining cement works and also by the formation of a very large spoil bank. The land was only hired by the corporation, and had therefore to be surrendered—it is unfortunate that the best part was thus taken. A scheme has been prepared for dealing with the increased flow of sewage, but as it has not yet come before the Local Government Board no details can be published.

SOUTH NORWOOD.

HISTORY.

Reference is made also to this farm by the Rivers Pollution Commission, First Report, Vol. I., pages 85 to 87 (1870).

About 30 acres of low-lying clay land with sufficient slope for natural surface drainage have been well laid out for irrigation. The drainage of about 4,000 people is received into a subsidence tank at the upper end. Periodical analyses extending over a whole year (September 24, 1868, to September 24, 1869) were made, and I have worked out the average for the effluents (see No. 2 below). Figures are given of samples taken on February 25 and March 12 and 25, 1869 (see Nos. 3 and 4 below). It would appear that the "average composition of the sewage" (see No. 1 below) is merely a repetition of No. 3 sample figures. Judging from the chlorine the average for the year should be much higher—on July 15th the chlorine in the effluent was 13.10.

in a stiff clay soil. The *Dry-weather Flow* is 600,000 gallons, and the *Storm Flow* has at times exceeded a rate of 4,000,000 gallons in twenty-four hours. The *Water Supply* is from wells sunk in the chalk. The *Rainfall* is 24.04 in. per annum, and the *Drainage Area* of districts sewered 1,200 acres. *Flushing*.—There are large automatic tanks, tipping tanks, and flushing vans and hose. The average *Stay in Sewers* is one hour and the *Distance* under 1 mile. *Screens* with 1-in. and $\frac{1}{4}$ -in. spaces are provided except to the 15-in. sewer. *Pumps* are employed to raise the sewage 10 ft., 15 ft. or 24 ft. to the highest portion of the farm (about 33 acres), which lies considerably above the level of the outfall sewers. The effluent from some of the land near the bottom of the farm can, if necessary, be pumped up to the highest land, a 15-in. underground pipe conveying the partially treated effluents back to the pump well. *Settling Tanks*.—The bulk of the sewage

SEWAGE AND EFFLUENTS (PARTS PER 100,000).

	Total Solid Matters in Solution.	Organic Nitrogen.	Ammonia.	Nitrogen as Nitrates and Nitrites.	Total Combined Nitrogen.	Chlorine.	Suspended Matters.		
							Mineral.	Organic.	Total.
(1) Sewage	94.9	1.586	6.032	.000	6.554	8.66	—	—	—
(2) Effluents	87.7	.271	.721	.481	1.340	9.11	—	—	—
(3) Sewage	94.93	1.586	6.032	.000	6.554	8.66	4.55	9.89	14.44
(4) Effluents	84.70	.255	.765	.422	1.307	7.36	Trace	Trace	Trace

REPORTS TO THE ROYAL COMMISSION.

Separate or Combined. — The

The Sewage. sewerage system is partially separate, about two-thirds of the streets having duplicate sewers for surface water and for the rain from the front portions of roofs. The streets are macadam or gravel. The sewage is entirely *Domestic*. There is very little *Subsoil Water*, as the sewers have been well constructed and are laid

passes through two settling tanks, each 60 ft. by 12 ft. by 3 ft. 4 in. average depth, provided with scum hoards. Both are used together continuously, and they are cleaned out once a week by means of mechanical bucket elevators discharging into adjacent sludge beds. The sewage from the 15-in. low-level sewer flows through a small tank, or catchpit, from which the sludge is removed by hand each week. The *Stay in Tanks* is from one to one and a half

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hours. Part of the *Sludge* (about 35 tons, wet, weekly) is sold and part used to fill up holes in a disused brickyard on the farm. The *Analysees*, both chemical and bacteriological, of the sewage will be

The *Lime* (parts per 100,000) dissolved by water in twenty-four hours is for soil 0·073, subsoil 0·020; and dissolved by water saturated with carbonic acid in forty-eight hours, for soil, 0·382, subsoil 0·076.

MECHANICAL ANALYSIS.									
Fine gravel (above 2 mm.) – medium sand (above 0·25 mm.)	...	...	...	...	...	...	...	...	4·15
Sand (0·25–0·5 mm.) – silt (0·05–0·01 mm.)	...	...	...	...	...	...	...	...	52·30
Dust (0·01 mm. – settling from water within 24 hours) – clay (still finer precipitated by dilute nitric acid)	...	...	...	...	...	...	...	...	25·29
Loss on ignition (separate determination)	...	...	...	...	...	...	...	...	12·03
									93·77

found at the end of this section compared with those of the effluent and of the stream.

Soil and Subsoil.

The *Soil*, stiff and heavy, is from 6 in. to 10 in. deep, and has been lightened in one or two parts by the digging in of ashes. The *Subsoil* is also stiff and heavy, partaking more of the nature of a brick-earth, resting on the London clay. The *Under-drainage* extends over about 25 acres. The drains are 4-in. and 6-in. socketted pipes, and are laid at an average depth of about 2 ft. They are about 12 yds. apart, and were put in to assist waterlogged plots to dry. *Subsoil Water and Floods*.—There is no subsoil water on the farm, and the land is not liable to floods.

The *Mechanical Analysis* given above shows the

Acreage, Population, &c.

The total area of the farm is 191 acres, and of this 152 acres are available for sewage treatment. The average area under irrigation at one time is 51 acres; the population served is 21,000, which works out at 138 persons per irrigable acre, or 415 persons per acre for the average area irrigated. The normal dry-weather flow is 28·5 gallons per head per diem. The amount treated per acre for twenty-four hours at the normal rate of flow is 12,000 gallons on the average area irrigated, equal to 4,000 gallons on the whole irrigable area.

Treatment and Cropping.

Treatment.—The sewage is treated on separate plots, either two, three or four times, being run over the surface of the land in a thin sheet,

DATES OF VISITS, MEAN TEMPERATURES, RAINFALL, &c.					
Dates of Visits.	Mean Temperatures (deg. Fahr.).			Mean daily Rainfall (inches).	Remarks.
	Air.	Sewage.	Effluents.		
1900.					
January 9-29	39	46	41	·06	—
November 7-23	44	47	47	·09	·42 rainfall on November 17th
November 27–December 20	45	50	49	·06	Experiment
1901.					
January 2					
1902.					
January 14-20	—	—	—	·00	Twenty-four hours' sewage samples

percentage composition of the ignited soil. The subsoil was not analysed.

The approximate number of particles in 1 gramme was 1,448,196,680, and in 1 c.c. 1,772,144,510.

picked up in a carrier at the bottom of the plot and passed over other plots in a similar manner. The effluents from the drained area are brought to the surface lower down the farm and re-treated. The

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higher land on the farm has a somewhat sharp fall, and the sewage is contoured over this part. The same plots are used continuously for from two to four days. The *Experiment* will be dealt with hereafter. *Cropping*.—The greater portion of the farm is laid down with rye grass. Mangolds, oats and mint are also grown, part of the crops being sold and part of the rye grass made into hay.

Analyses—
Sewage, Effluent
and Stream.

The sewage is purely domestic, and it is screened and settled, a small portion being settled without screening. The chief

Chemical results are:—

rather weak sewage and a relatively small amount of organic matter per acre of irrigable area. The clayey surface soil is not a very deep one—only 6 in. to 10 in.—but it has been to some extent improved and lightened by the digging in of ashes, and also, of course, by the sewageing which it has received . . . So far as one can draw a conclusion from the analyses of the final and general effluents—which are fewer in number than might have been wished—these effluents were of moderate quality, the land having evidently had rather too much to do in January and November, 1900. This was fully recognised by the authorities, who were at that time extending their bacterial filters. As has been already noted, the

CHEMICAL ANALYSES (PARTS PER 100,000 BY WEIGHT).			
—	Sewage.*	Effluent.† (5-11 samples.)	Stream. (1 sample.)
Total nitrogen	6.135	2.30	0.75
Ammoniacal nitrogen	4.615	0.87	—
Total organic nitrogen...	1.875	—	—
Albuminoid nitrogen	0.815	0.10 { 87.1 per cent purification (average) }	—
Oxygen absorbed 4 hours at 80 deg. Fahr.	9.555	1.44 { 84.1 per cent purification (average) }	0.64
Nitric and nitrous nitrogen	—	0.39	—
Chlorine (in water supply 1.3)	7.66	—	3.20
Incubator test as judged by smell	—	— { 75 per cent passed (12 samples) }	No smell
Solids in suspension (hourly samples only)...	21.9	—	—

* Approximate averages of seven sets of samples drawn in equal quantities per hour for 24 hours and of four to seven chance samples.
† Including three two-field effluents.

“ These effluents varied in appearance, the general effluents evidently containing rather more suspended matter than the others; but it is only fair to note that when No. 31 (a general effluent) was drawn, the rainfall had largely increased the flow, and there had also been heavy rains previous to the drawing of No. 35, another general effluent. From an excellent looking effluent with a slight brown tinge and only a trace of flocculent matter (No. 180), there were others which were turbid and with appreciable amounts of matter in suspension. The smell, when the samples came to be analysed, varied from fishy to earthy. The few samples which were tested for reaction were alkaline, and they contained a great deal of lime and a good deal of sulphate in solution.” (Part II., page 162.) “ The South Norwood farm treats a relatively small volume of a

difficultly of treating sewage by broad irrigation on a clay soil, in which the aggregate effective surface for purification is small, must be greatly added to by sudden and irregular flushes of storm water. It seems also open to question whether it is advisable to continue sewageing one plot of ground for so long a period (from two to four days) as is actually done at South Norwood. It would make an interesting and useful experiment to try (not merely at South Norwood but at other farms also) the separate effects of treating equal quantities of the same sewage on equal areas of ground, but in the first case with more frequently intermittent doses than in the second.” (Part II., pages 163 and 164.)

The *Bacteriological* figures may be summarised as on following page.

“ The results, judged as a whole, do not lend

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colour to the belief that land of the kind available at the South Norwood sewage farm could be worked in practice so as uniformly to yield a really good effluent. But as so many of the final and general effluents either passed or came within measurable distance of passing the standards suggested, it may

of this little stream often does not exceed that of the farm effluent, while the engineering report states that in dry seasons very little effluent leaves the farm at all owing to evaporation. The samples of water examined contained very appreciable amounts of brownish flocculent matter in suspension, and

BACTERIOLOGICAL ANALYSES (TOTAL NUMBER OF BACTERIA PER C.C.).				
—		Sewage. (4 samples.)	Effluent.* (9 samples.)	Stream. (1 sample.)
(1) Gelatine at 20 deg. C.		48,600,000	778,322 { 98 per cent reduction }	7,900
(2) Agar at 37 deg. C.		6,357,500	35,157 { 99 per cent reduction }	1,100
(3) B. coli or closely allied forms (say at least)	...	100,000	470 { Varied from at least 10 to 1,000 not 10,000 }	100 not 1,000
(4) B. enteriditis sporogenes (spores—say at least)		550	47 { Varied from at least 1 but less than 10 to at least 100 but less than 1,000 }	None in 1 c.c.
* Satisfactory (1) 3, (2) 4, (3) 5 and (4) 3 out of 9 effluents in each case.				

be added that, if an additional area of land could be acquired so as to reduce the existing dose of sewage per acre of land, a majority of the resulting effluents would doubtless be found to be fairly satisfactory." (Part III., page 108.)

Effluent and Stream Compared. The effluent leaves the farm by an open ditch joining the Chaffinch Beck a small distance away. The ratio of effluent to brook water at the second time of sampling was 3 to 1. A small amount of

showed too much oxidisable matter generally. There was no question of nuisance arising, and three out of the four samples were well aerated when analysed, but the relatively high figures for "oxygen absorbed" showed that, from one cause or another, this little brook—judged from a brook-water standard—was not in a very satisfactory condition at the time the few observations were made.

The analytical tables are unfortunately incomplete as regards the first four samples (effluents), which

DISSOLVED OXYGEN (PARTS PER 1,000=C.C'S. PER LITRE).						
—			Boiled out.	Cuprous Chloride at time of		
				Drawing.	Analysis.	
Effluent	...	...	1.73 — 6.05 average	4.32	0.5 — 3.0 average	2.1
Stream	...	...	— — — —	8.35	— — — —	1.0 — 5.75 average
Mixture	...	...	6.54 — 7.20 „	6.87	— — — —	2.54
					3.5	— — — —
						2.75

sewage weed was noticeable in places, but this may not be due to the effluent but to surface-water drains which flow into a ditch joining the effluent before reaching the Chaffinch Beck, the ditch itself containing similar weed. Even in winter the volume

makes any detailed criticism more difficult, but the samples drawn in November, 1900, appear to have been rather better on the whole than those drawn in January, though they certainly contained much less dissolved oxygen when analysed. Of the January

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samples two had as much as 5 c.c. to 6 c.c. per litre of dissolved oxygen when analysed and one about 3 c.c., the amounts in the four others tested being about 1 c.c. in each case; but when the January set of samples was drawn and analysed the temperature was lower. The gases in the January samples were hoiled out. Samples tested for dissolved oxygen when drawn (five in number) did not apparently give high results, the maximum figure being 3 c.c.; but as these effluents were all more or less coloured, the comparison with the standard copper chloride tubes was difficult; hence those dissolved oxygen figures in the November sample must be taken as being almost certainly below the true value, and no real conclusions can be drawn here. The heck water was fully aerated when analysed and the "mixture" generally so—all kept sweet upon incubation.

Nuisance and Difficulties. No mention is made of nuisance arising from the sewage operations. The chief difficulty experienced in the working of the farm is the selling of the crops.

Conclusions. "The sewage (purely domestic) is weak. South Norwood may be taken as an example of a surface irrigation farm (with a little filtration). It was treating both per acre of the 'working' daily irrigable area, and per acre of the total irrigable area, a small volume of sewage, and a very small quantity of organic matter in the aggregate. The soil (a partially modified clay soil resting on London clay) is not very well adapted for purifying even a moderate volume of sewage. The sewerage system is partially separate. All the storm water reaching the sewers is dealt with on the farm. We consider that even 12,000 gallons per acre per twenty-four hours (4,000 gallons per acre of the total irrigable

area per twenty-four hours) is possibly too large a volume of even a weak sewage to be treated by screening, settling and surface irrigation (with some little filtration) on surface soil of the above nature. Nevertheless, it should not be forgotten here that the difficulty of treating the storm water at South Norwood must be relatively great. In comparing Leicester and South Norwood—two typical clay farms—it should further be remembered that although the Leicester farm was treating a much larger volume of sewage per acre and a larger amount of organic matter in the aggregate, it had to deal with much less storm water, and in all probability benefited to a greater extent by filtration, which, however, must in any case have been comparatively small." (Part I., page 91.)

NOTE.—At the time of visiting the farm bacteria beds (single contact) were being constructed; one small one was in active use and treated screened sewage. The effluent therefrom passed over the land and finally mixed with the general effluent on leaving the farm.

LATER WORK.

Since 1900 the population draining to the farm has largely increased, and the sewage is now in some measure partially purified before being applied to the land. In 1901 five single-contact bacteria beds of a total area of $\frac{3}{4}$ acre were finished. They were filled to a depth of about 3 ft. 6 in. with ballast hurnt on the site. In 1905 three storm filters (about 1 acre) were made and a detritus tank to the low-level sewer was built. An extension of the five bacteria beds is now in hand, and the area of these when completed will be $1\frac{1}{2}$ acres. It is proposed to fill them twice on weekdays and once on Sundays, and to give each bed one week's rest in turn. The bottom of the shallow pits formed by the excavation of the clay to make ballast is so impermeable that it has not been found necessary to lay any concrete as a floor to these beds.

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SUMMARY OF PARTICULARS.

	Aldershot Camp.	Altrincham.	Cambridge.	Croydon (Beddington).	Leicester.	Nottingham.	Rugby.	South Norwood.
Proximity to town } sewered (miles)	Less than 1	2	3	3	2	5	1	Less than 1
Total area (acres) ...	138.5	75.5	102.5	673.5	1,699	907	40	191
Surplus acreage = p.c. of } total	18 = 13	40 = 53	28 = 27	253 = 37	349 = 20	256 = 28	5 = 12	39 = 20
Irrigable area (acres) = } p.c. of total	120.5 = 87	35 = 46	74 = 72	420 = 62	1,350 = 79	651 = 71	35 = 87	152 = 79
Average area irrigated at } one time (acres) = p.c. } of total irrigable area	40 = 33	17.5 = 48	18.5 = 24	70 = 16	337 = 25	300 = 46	7 = 20	51 = 33
Population ...	20,000	18,000 (a)	50,000	100,000	197,000 (b)	258,584 (b)	6,000	21,000
Population per acre (total } area)	145	240 (a)	490	148	116 (b)	285 (b)	150	110
Population per irrigable } acre	166	514 (a)	676	238	146 (b)	397 (b)	171	138
Population per irrigable } acre above or below } the mean (305) = p.c.	{ -139 = 45 } below }	{ +209 = 68 } above (a) }	{ +370 = 121 } above }	{ -67 = 21 } below }	{ -159 = 52 } below (b) }	{ +92 = 30 } above (b) }	{ -134 = 43 } below }	{ -167 = 54 } below }
Gallons of sewage per } head per day	50	44.4	45	40	36.8	27	50	28.5
Gallons of sewage per } head per day above or } below the mean (40) = } p.c.	+10 = 25 above	{ +4.4 = 11 } above }	{ +5 = 12.5 } above }	{ Average } number }	-3.2 = 8 below	{ -13 = 32.5 } below }	+10 = 25 above	{ -11.5 = 28.7 } below }
Dry-weather flow (gallons)	1,000,000	800,000	2,250,000	4,000,000	7,250,000	7,000,000	300,000	600,000
Storm water treated ...	{ Very little } separate } system }	Very little	Small amount	{ All from } sewers }	2½ times d.w.f.	Very little	Nearly all	{ All from } sewers }
Gallons of sewage (ex- } clusive of storm water) } per acre per 24 hours	25,000	46,000	121,600	57,100 (c)	21,500	23,300	42,800	12,000 (c)
Gallons of sewage (ex- } clusive of storm water) } per acre per 24 hours } above or below the } mean (43,662) = p.c.	{ -18,662 = } 42 below }	{ +2,338 = 5 } above }	{ +77,938 = } 178 above }	{ +13,438 = } 31 above (c) }	{ -22,162 = } 50 below }	{ -20,362 = } 46 below }	-862 = 2 below	{ -31,662 = 72 } below (c) }

Summary of Particulars.

Gallons of sewage (exclusive of storm water) per acre per 24 hours assuming whole irrigable area used	8,300	23,000	30,400	9,500 (c)	5,370	10,750	8,500	4,000 (c)
Gallons of sewage (exclusive of storm water) per acre per 24 hours above or below the mean (12,427) = p.c.	{ -4,127 = 33 below }	{ +10,575 = 85 above }	{ +17,973 = 144 above }	{ -2,927 = 24 below (c) }	{ -7,057 = 57 below }	{ -1,677 = 13 below }	{ -3,927 = 32 below }	{ -8,427 = 68 below (c) }
Characters of the sewage	Domestic	Mainly domestic	Mainly domestic	Mainly domestic	$\frac{2}{3}$ domestic, $\frac{1}{3}$ trade	$\frac{4}{7}$ domestic, $\frac{3}{7}$ trade	Mainly domestic	Domestic
Preliminary treatment	{ Screening and settling tanks }	{ Screening and settling tank — sewage pumped }	{ Screening and settling tank — sewage pumped }	Screening	{ Screening and settling tanks — sewage pumped }	{ Part sewage screened and pumped }	{ Screening, occasional chemical precipitation, and settling tanks }	{ Screening and settling tanks }
Land treatment ...	Filtration	Filtration	Filtration	{ Surface irrigation and filtration }	{ Surface irrigation and filtration }	Filtration	{ Surface irrigation and filtration }	{ Surface irrigation with a little filtration }
Soil ...	Coarse sand	Peaty	Sandy loam	{ Gravelly loam }	Stiff clayey	{ Sandy loam and gravel }	Clay	Clay
Subsoil ...	Very fine sand	{ Sand and gravel }	{ Gravel and sand }	{ Gravel and sand }	Dense clay	{ Gravel and sand }	{ Stiff clay with gravel pockets }	London clay
Approximate relative number of particles (ignited)	19	157	75	46	269	100	392	177
Sewerage system	Separate	Combined	{ Partially separate }	{ Partially separate }	{ Partially separate }	Combined	{ Partially separate }	{ Partially separate }
Approximate ratio dry-weather flow of effluent to volume of river	1 : 6 normally	1 : 3 normally	1 : 15 normally	{ 1 : 12 time sampling (1st) }	{ 1 : 1 time sampling }	{ 1 : 160 time sampling }	{ 1 : 30 time sampling (2nd) }	{ 3 : 1 time sampling (2nd) }
Number of years in operation before 1900	36 (d)	30	5 (systematic working)	39	9	19.5	33	36
Sludge disposal ...	On farm	On farm	On farm	On farm	{ Partially on farm }	On farm	{ Partially on farm }	On farm

(a) The surveyor to the urban district council informed me in August last of the partial conservancy (see page 17).

(b) Partial conservancy (see pages 35 and 43), but, on the other hand, considerable quantities of trade refuse.

(c) It should be noted that, were the storm water dealt with on the farms included, the volume actually treated per acre, especially in the cases of Croydon (Beddington) and South Norwood, would be very greatly increased.

(d) The extract from Colonel Jones's description of the management of the farm should be borne in mind (see page 11).

EXPERIMENTS.

At Croydon, as at South Norwood and at Leicester, experiments were made in order to see how long the purifying power of the soil would hold out under a daily increasing dose of sewage.

Croydon. The soil and subsoil at Beddington are comparable with those at Nottingham and Cambridge, though the Beddington subsoil is much the most stony of the three. The rate of filtration must also be somewhat similar to the rates at Nottingham and Cambridge, though no doubt appreciably faster. The results obtained in the above short experiment show very clearly (1) the high purifying power of the Beddington soil and subsoil, and (2) the much greater degree of purification that can be effected when such a soil is used for filtration rather than for surface irrigation. Experiments of this kind present great practical difficulties, and it is impossible, unless they are carried out during a prolonged period, to draw, from a bacteriological point of view, from them any conclusion of real value. The only interpretation that can safely be put on the bacteriological results is that land of the kind available at Beddington can purify, to a reasonable extent, relatively large volumes of sewage.

Leicester. This experiment, though not affording a direct answer to the question how much sewage an acre of the Leicester farm will purify, is in some ways instructive. First we have an effluent of indifferent appearance and not really purified, because of its having partly escaped into the drains through cracks in the soil, but kept non-purified in virtue of the accumulated nitrate which it has washed out. After that there is an improvement in purification up to No. 140, at which time it so happened that just about the normal flow for the Leicester farm was being treated. Then comes a gradual falling off though with a few minor fluctuations, until sample No. 147 is reached, when the effluent is temporarily benefited by rain, only to

relapse next day. In no case from No. 139 onwards is there any appreciable nitrate present in proportion to the total nitrogenous matter—that is to say, the purification effected is insufficient. These few observations thus emphasise the point that most careful management is required on a clay sewage farm. Perhaps the most practical conclusion to be drawn from them is that any effluent from clay land which is partly made up of liquor that has escaped through cracks in the soil should be subsequently passed *for certain* over some uncracked ground—*e.g.*, ground in the condition that the above plots were in shortly after the soil had been filled up with an excessive flow. It will thus be seen that the results in general were of an unsatisfactory nature. The first two effluents were very unsatisfactory, later on in the experiment the effluents improved in biological quality; but the results yielded by the different tests varied so greatly as to render it impossible to come to any but the general conclusion—namely, that the results throughout were unsatisfactory. Nevertheless, the percentage purification effected by the process was considerable. Briefly, it may be said that under the conditions of the experiment the land failed to purify the sewage to a satisfactory extent. To obtain definite results from experiments of this kind the investigation would need to be extended over a period of several months, or even years, and this under the circumstances, of course, was out of the question.

As the conditions of this experiment were decidedly abnormal, both because of the large reserve of nitrate in the soil and the slow way in which this nitrate was given up, and also because of uncropped arable land only having been used, one cannot safely draw any further conclusions from the results with regard to the purification which the South Norwood farm might ordinarily effect. As regards the general bacteriological results, it appears that the effluents were at first very bad, later they improved somewhat, although sample 190 (one plot)

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was most unsatisfactory ; still later, from the time when Mr. Kershaw noticed that the land was beginning to smell until the close of the experiment, the results were undeniably unsatisfactory. Too much stress must not be laid on the importance of these experimental observations. To be of real use the investigation would need to be modified in a number of ways and extended over a period of some years. But, broadly speaking, the results are of some interest, since they tend to show, as might have been anticipated, that the continuous application of sewage (in the amounts stated) to land of the kind available at South Norwood speedily results in fonging of the land, and in the production of evil odours and objectionable effluents. Nevertheless, considering only the early stages of the experiment, a fair proportion of the second plot effluents was satisfactory. The marked (as a rule) difference between the first and second plot effluents is worth noting, because it tends to show that, given an adequate area of land available for sewage purification purposes, land even of an unsuitable character can probably effect any reasonable degree of purification.

NEW LAND.

In preparing a new area for
Aldershot Camp. sewage the land is chalked, ploughed, harrowed and rolled, all slack places being filled in and the ground thoroughly levelled ; contour grips are cut and the tank effluent let into the contours from the main carrier through sluices. The contour grips in filling gradually overflow in a thin stream over the land until reaching the next grip, when the sewage is cut off and applied to the next succeeding grip, the same

operation taking place. Plot "A" was brought into operation in May, 1900, and plot "B" in June, 1901. "A" was sown with rye grass and sewage applied for about fourteen days, when the land was rolled. Sewage was put on again immediately after the rolling. Since then it has been sewage after the cutting of each crop in much the same way as the old land. Both chemically and bacteriologically the samples from "A"—viz., (1) May and June, 1900, (2) July, 1901, and (3) October, 1901—were all bad. Further samples (4), January, 1902, could be termed high-class effluents chemically, and yielded, from a bacteriological standpoint, on the whole remarkably good results. The data obtained "are of very great interest as showing how long a time was required—from one cause or another—to bring this plot of absolutely sandy soil into a fit state for purifying sewage. This slow ripening of the sandy soil may have been due, among other things, to the great ammoniacal strength of the sewage ; to the dose of sewage having been at first too large ; to the small quantity of lime in the soil ; and to the ground not having been properly consolidated." (Part II., page 20.) "It is difficult to understand why this plot of land should have improved in purifying power to so marked an extent since July 23, 1901. Mr. Kershaw, however, supplies a note to the effect that probably the very heavy rain falling at this period (January, 1902) may have considerably diluted the effluent." (Part III., page 29.) The effluents from "B," while distinctly better than the early effluents from "A," were still not at all good, oxidation not having gone far enough. The superiority may have been due to the better state of consolidation of the ground when the sewage came to be applied.

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PARTICULARS OF OTHER FARMS VISITED.						
—	Luton.		Worsley (Barton Old Hall), near Manchester.	Hemsworth, Yorkshire.	Derby County (Mickleover) Asylum.	Sandhurst, Berkshire.
	High Level.	Low Level.				
<i>The Sewage.</i> Separate or combined	One-fourth streets separate		Partially separate	—	Some roof and gully water from farm buildings and yard	—
Domestic or mixed	One-third from straw-plait industry—i.e., bleaching (peroxide of hydrogen and silicate of soda), dye refuse (logwood, &c.), and large quantity gelatine. Solids only arrested by manufacturers—screens and sumps		Dye and bleach refuse considerable quantity—proportion not ascertained	Slaughter - house refuse (Wednesdays only)	Asylum sewage and liquid manure from farmyards—part of latter taken from tank and used	—
Total flow (gallons)	1,700,000		300,000	70,000	30,000	15,000
Water supply (gallons)	24 per head		—	—	50,000 pumped daily from deep well	—
Rainfall (inches) ...	25.3		—	—	—	—
Storm overflows ...	—		—	Overflow operates before half capacity 15-in. sewer reached	—	—
Screens ...	Roughing screens before pumping		—	—	Cage screen and small chamber	—
Pumps ...	Raise sewage 42 ft.—125 ft.		—	—	—	—
Settling tanks ...	At pumping station 1,750,000 gallons—cleaned once fortnight—one reserved for storms At farm—Capacity 1,500 cub. yds. wet sludge—emptied three times per year		—	In duplicate, one set of three used at one time—16 ft., 14 ft. and 12 ft. long by 15 ft. wide and 3 ft. 4½ in. deep	Farmyard manure into tank for use	In duplicate Are provided
Screenings ...	—		—	5 tons per week—mixed with ashes, difficulty disposing	Dug into land	—
Sludge ...	Farmers remove		—	1½ in.—2½ in. (ashes dug in)	—	—
<i>Soil and Subsoil.</i> Soil ...	Loose porous loam, 4 in.—10 in. on hill; several feet in valley		Northern part gravel and sandy soil—southern part 5 ft.—6 ft. pure peat	—	3 in.—4 in. where untouched—stiff nature	Similar to Aldershot Camp but rather better and more top soil
Subsoil ...	Chalk, exceedingly loose, rotten and full of cracks		Peat (as above) overlying fine white sand	6 ft. stiff yellow clay over boulder clay	Red clay	ditto Clay

Particulars of Other Farms Visited.

Under-drainage ... Acreage, Population, &c. Total area (acres) Available area } (acres) Average area irri- } gated (acres)	5 ft. deep; 40 yds. — 50 yds. apart	3 ft. deep—18 ft. apart	3 ft. 6 in. deep	3 ft. deep	4 ft. deep
71	127	4	—	13	8
56	40*	3	25	—	—
20	8—10	—	—	—	—
38,500	10,000	3,200	800—1,000	600—700	—
Persons per irri- } gable acre } Normal } weather flow per } head per diem } (gallons) Amount per acre } on average area } irrigated (gal- } lons) Amount per acre } on whole irri- } gable area (gal- } lons)	250 (+ trade effluents) 30 (including trade effluents) 15,000—30,000 7,500	— 22 23,300 —	16 30—38 30,000 1,200	— 23 1,100 —	— — — —
Treatment.	Same area 12 hours by day and 6—12 hours by night for one month (some- times two)	Land laid out level in two terraces (very narrow) 1—7 days	Down one furrow till bottom reached — then next; 1 acre per 24 hours	As at Aldershot Camp farm	—
Cropping.	Narrow beds planted with various crops on ridges Hilly part—rye grass—flooded	Not cropped—fre- quently dug over	—	Rye grass and mangolds	—
Analyses. (Investigation too short and analy- ses too few as data for definite conclusions)		See notes p. 66			
Remarks.	Effluent obtained (after removing sur- face soil) from pocket in side of pit— effluent disappears vertically, indi- cating great caution re wells near farms on chalk	Alumino - ferric occasionally used to assist sedimen- tation; bulk work filtration through stoned rubble and ashes over under- drains—land ex- pected to treat more than 7 times usual	Farm never pro- perly laid out for sewage — land cracks badly and sewage passes off in under-drains	—	—

NOTES ON OTHER FARMS VISITED.

Luton. *Engineering Notes.*—Cities and towns such as Winchester and

Luton, whose sewage farms are on the chalk, find themselves in the fortunate position of being untroubled by effluents, for the sewage at these places sinks into the ground and disappears. For this reason attention may be drawn for a moment to the effluents obtained artificially by the filtration of the Luton sewage through different thicknesses of chalk *in situ*, with previous removal of the surface soil. The results of the chemical analyses showed that the sewage underwent comparatively little direct purification in its rapid passage through 3 ft. of chalk. This emphasises the necessity for the careful examination of all well and spring waters which could by any possibility come within the sphere of influence of a chalk sewage farm. *Chemical Notes.*—The partially settled sewage was moderately strong as regards nitrogenous matter, but the “oxygen absorbed” figures were rather low. The effluent was obtained after the removal of the surface soil and appeared in one and a half minutes. It contained phenomenal amounts of nitrate—one sample taken during heavy rain yielded twenty-four parts of nitric nitrogen per 100,000. The top soil was rather rich in nitrate, there was less in the chalk and it diminished with increased depth. *Bacteriological Note.*—All the effluents gave very bad results, and were not bacteriologically remote from samples of untreated sewage.

Worsley. *Engineering Notes.*—The Worsley farm effluents from that portion of the farm which consisted of

pure peat land were, as might have been expected, far from satisfactory, though even here there was a very considerable degree of purification. Without at all recommending peat land for the treatment of sewage, it is interesting in this connection to recall a laboratory experiment made by the Rivers Pollution Commission (First Report, Vol. I., page 69), as follows: “These analytical results show that, although the action of the Lancashire peat upon sewage is for a couple of months but slight and

unsatisfactory, yet the subsequent steady improvement of the effluent water encourages the hope that this material would, after a somewhat longer education, become an efficient purifier of sewage filtered through it at the rate of 49 gallons per cubic yard per twenty-four hours.” *Chemical Notes.*—The nitrogenous matter was moderate and the “oxygen absorbed” relatively high. All four effluents from the peat land were bad, or nearly so. Peat is unsuitable, as it acts like a sponge; there is the difficulty of draining it and the consequent lack of aeration. *Bacteriological Note.*—The results, considered in relation to the peaty characters of the soil on the farm, are surprisingly good and do not, from the bacteriological point of view, altogether support the opinion so generally held that peat is quite unsuitable for sewage purification purposes.

Hemsworth. *Engineering Notes.*—See Derby County Asylum. *Chemical Notes.*

—The crude sewage was distinctly strong and the settled sewage fairly so. The two samples of effluent were very bad. *Bacteriological Note.*—The effluents were unsatisfactory, though one passed the B. coli test.

Derby County Asylum (Mickleover).

Engineering Notes.—The Mickleover and Hemsworth farms afford instances of sewage treatment on very shallow surface soils overlying stiff clay—i.e., on types of soil not well adapted for the treatment of sewage. But even under such unfavourable conditions the Mickleover effluents furnish an illustration of the point emphasised elsewhere in this report—viz., that (the question of) purification by a soil is one of degree rather than one of intrinsic ability or disability. *Chemical Notes.*—The sewage was not particularly strong so far as nitrogenous matter was concerned, but the “oxygen absorbed” was excessively high in proportion. Speaking generally, the effluents were better chemically than they looked, but the system is faulty and solids in suspension should be eliminated by running

Land Treatment of Sewage.

over undrained land. *Bacteriological Note*.—All the effluents were unsatisfactory.

Chemical Note.—The sewage and effluents were weak; the latter did not withstand the incubation test.

Bacteriological Note.—The samples of effluent were not satisfactory, but a high percentage degree of purification as compared with the settled sewage was effected.

Chemical Notes.—The sewage was distinctly strong both as regards nitrogen and oxidisable matters generally. The effluents were bad. *Bacteriological Notes*.—The sewage yielded exceptionally high figures (one sample, 102,400,000 gelatine at 20 deg. C. and 13,360,000 agar at 37 deg. C.). The effluents in comparison were remarkably good.

DR. POORE'S SYSTEM.

The author of this system very kindly attended the discussion on the paper I had the honour of reading at the Surveyors' Institution on January 12, 1903, and said he had to thank me for the very clear statement of his views and practice. A short summary from that paper ("Rural Drainage and Sewage Disposal"*) may, therefore, be not out of place. The burial of putrescible refuse in the upper layers of cultivated soil has been the successful practice of the agriculturist in all ages and climates. For over eighteen years the garden of the late Dr. Poore received daily (Sundays excepted) the fæces from nineteen to twenty-three cottages. These fæces were packed methodically in shallow parallel furrows (less than a spit deep) and carefully covered. It is well, both from the economic and sanitary standpoints, to take two crops from the soil thus treated; the first of the cabbage order, the plants being dibbled in at the earliest opportunity. The garden in question is near the centre of the town of Andover, has 1 a. 1 r. 7 p. devoted to spade culture, and receives the fæces of about 100 persons. Most scavenging schemes are doomed to failure by reason of the cost of collection and transport. The distance travelled and the weight carried are needlessly great. A daily removal is to be aimed at, as being most sanitary and economical. The buckets used for the conveyance of fæces must be scraped out and dusted with soil or ash—soil being the best of all deodorants and antiseptics. In the middle of the garden is a shallow well, about 5 ft. 6 in. deep,

the sides lined with concrete, and in ten years no sign of mud has appeared. The slop water, which is not foul-smelling until putrefaction sets in, should be discharged first through a strainer (a basket with a wisp of straw, to be changed on becoming clogged), then through a coarse filter (a galvanised-iron bucket with a hole at the bottom and filled with coke or clinker), and finally into a filtration gutter (a perforated gutter laid upon coarse rubble of any kind), the sides of the gutter being planted with moisture-loving plants such as black currants or raspberries. The reduction in the uppermost layers of the soil of fæces to humus is largely due to the growth of fungoid organisms. Dr. Poore appeared before the Commission on May 21, 1901 (pages 510 to 516), and the following notes are from Part II, pages 241 and 242; Part III., page 160; and Part IV., page 114. There is a good depth of soil (about 4 ft.) in the garden overlying the chalk. A sample of well water, drawn while fæcal matter was being dug in at a distance of 50 ft., was found to be exceedingly pure chemically, and to maintain its aeration after being incubated; bacterially the results were surprisingly good, but the presence of bacillus coli in 1 c.c. showed that contamination, presumably of animal sort, was not altogether absent. The crops of fruit and vegetables were phenomenal. The weak point of the system would be shown by a long-continued frost, rendering the ground too hard for cultivation. The arrangement for disposing of slop water would not, of course, be so easily carried out on a stiff non-porous soil.

Though taken to task somewhat I was unable to change my views on his system, nor have I since found any reason to alter my opinion, which was expressed as follows: "Unless and until our rural population have overcome the prejudices and altered the habits of generations, I fail to see how the system so strenuously advocated by Dr. Poore can be widely adopted. The experience of all concerned with sanitary matters in relation to small property leads to the conviction that there is no class more prone to neglect that constant attention on which the success of the whole operation depends. In his own case supervision (unpaid, be it noted) is assured, because the doctor himself runs the experiment as a hobby. His gardener also is interested in getting daily as much manure as he can, because he receives a percentage on the amount realised by the sale of the garden produce, and could readily make use of much more material . . . The general opinion, however, will be that in most cases the daily disposal of fæces by burying, and of urine, sink and slop wastes

* THE SURVEYOR, January 18 and February 8, 1903.

Land Treatment of Sewage.

by strainers, filtration gutters, &c., is one which cannot be employed except in those rare instances where constant pressure can be brought to bear, and where it is to the interest of someone continually to look after things."

BURIED SLUDGE.

Some of the sludge (dug up in Cambridge. 1901) which had been buried 18 in. deep five years previously resembled a dense black clay. Various chemical experiments and analyses were made, and the conclusion was drawn that sludge should never be buried in masses, but should be thoroughly admixed with the soil in its upper layers.

SUNDRY NOTES.

Attention has already been drawn to the waste of nitrate and other manurial constituents in the effluent from the Aldershot Camp farm (see page 15 under the heading "Effluent and Stream Compared"). In the paper "Rural Drainage and Sewage Disposal," referred to on page 65, I raised the point that effluents were valuable (regarded for the moment as water only) for irrigation. On that occasion and previously, February 12, 1900, "The Bacterial Treatment of Sewage"* I made some remarks on the manurial value of effluents, and I am now more convinced than ever that this branch of the sewage problem—the utilisation of effluents—will prove both practicable and profitable.

As is well known, sewage when diluted with rain water is at times discharged by means of storm overflows into rivers in the "untreated" condition. For practical reasons it may be impossible to insist on the treatment of more than a few times the dry-weather flow of sewage. But it should be remembered that sewage diluted even six or more times with pure water would still remain a liquid almost as potentially dangerous to health as normal crude sewage. During the course of the investigation only a few samples of storm water were collected. But since then a fair number of samples has been examined from other places, and the results obtained confirm the truth of the above statements. On the other hand Dr. Houston says, when dealing with Croydon: "It ought to be remembered that a large access of storm water not only at the time of its introduction affects injuriously

the working of a sewage farm, but may also so disturb the equilibrium of the biological conditions, which make for purification of the sewage, as to exercise a more lasting prejudicial effect." (Part III., page 73.)

Artificial Storm Waters.

The consideration of storm waters illustrates very clearly the weak points of what may be called an "absolute"* standard for effluents. In connection with this the following experiments were done: Six artificial storm waters were made at different times from Beddington (Croydon) and South Norwood sewages by diluting them down to (a) the Mersey and Irwell provisional effluent standard for albuminoid nitrogen (0.12 part per 100,000), or (b) to half that standard (0.06 part) with tap water; the latter, of course, contained dissolved oxygen and, in addition, some nitrate.† These liquids were then allowed to stand for six to twelve days in full hottles, either at laboratory temperature or at 26.7 deg. C. (80 deg. Fahr.). In every case, excepting possibly one (a sample diluted to half the Mersey and Irwell standard), the mixture was eventually found to be putrid. Three other samples were diluted with tap water to the Mersey and Irwell effluent standard for albuminoid nitrogen, and quantities of potassic nitrate were added equal respectively to 0.1, 0.2 and 0.3 parts nitric nitrogen per 100,000 of liquid. After incubation at 26.7 deg. C. (80 deg. Fahr.) for seven days these were all found to be putrid. Three more samples were diluted with distilled water to the Mersey and Irwell effluent standard for albuminoid nitrogen, and quantities of ammonium nitrate were added equal to 0.3, 0.15 and 0.075 part nitric nitrogen per 100,000, the last sample being then diluted further with three volumes of tap water. After incubation for six days all those three solutions were found to be sweet. The results of the above experiments are thus to some extent contradictory, but taken all over they show: (1) That dilution of a sewage with tap water down to the Mersey and Irwell effluent standard for albuminoid nitrogen gives a mixture which putresces upon incubation. In other words such a mixture is far more liable to putrefaction than an effluent of apparently the same strength as judged by the albuminoid nitrogen test. Even when the dilution is carried twice as far—i.e., down to half

* The term "absolute" is not really distinctive, but it may serve for want of a better.

† Two samples of this tap water, examined at a later date, were found to contain approximately 0.25 and 0.30 part of nitric nitrogen per 100,000.

* THE SURVEYOR, February 16th and 23rd and March 2nd, 1900.

Sundry Notes.

the Mersey and Irwell standard—the mixture will, in all probability, be putrescible upon incubation. (2) That an added quantity of nitric nitrogen (up to 0.3 part per 100,000) to a dilute sewage of the Mersey and Irwell albuminoid nitrogen standard for effluents may not be sufficient to prevent this putrescence upon incubation, although on the other hand it may. (See Part II., pages 322 and 323.)

Seven samples were examined—
Surface *viz.*, two from Aldershot Camp,
Street Washings. one from Rugby, and four from
South Norwood. Three of the samples contained so little organic matter that they withstood the incubator test, but the others did not; of those four others two might be classed as dilute sewages, the remaining two being weaker. Although the above samples were few in number, they show, at all events: (1) That even when a street water is comparatively pure organically it requires settlement for grit, and (2) that even after long-continued rain street surface

waters may be very impure. It has been perhaps too readily assumed in the past that the storm liquid resulting from the adoption of the separate system is relatively unobjectionable. From the bacteriological point of view this liquid may be grossly and dangerously (potentially speaking) impure.

“The few samples of subsoil
Subsoil Water. water collected in the neighbourhood of some of the sewage farms were usually found to be pure, both chemically and bacteriologically; but this, of course, must not be regarded as proving that wells sunk in such situations are safe for domestic use, or free from serious objection. Two years' work by one of us on the chemical and biological qualities of the Chichester well waters showed that shallow wells sunk in polluted soil and subsoil may show, on searching bacteriological examination, unequivocal evidence of excremental, and, therefore, potentially dangerous, pollution.” (Part I., page 105.)

GENERAL CONCLUSIONS.

Bacterial
Condition
of
Effluents.

The effluents of sewage farms are not bacterially in a proper condition for discharge into drinking-water streams—the bacterial flora is characteristic of sewage and the microbes of the soil are relatively absent. Though the sewage as the result of land treatment does not seemingly become modified in its biological characters to any material extent, yet the numbers of the bacteria are markedly reduced. All the samples of river water taken above the outfalls were contaminated bacteriologically from the point of view of drinking water, and they were not always satisfactory, either chemically or bacterially, in respect of non-drinking water streams. “Generally speaking, the discharge of the effluents into the respective streams did not exercise any marked prejudicial effect on the water of the stream; indeed, the reverse was sometimes observed. There seems to be no reason to doubt that the effluents from properly-managed sewage farms would, when discharged into non-polluted streams of relatively large volume, neither give rise to any nuisance, nor, so far as may be judged by rate of absorption of oxygen, prove injurious to fish.” (Part I., page 105.)

Discharge
Effluents
No
Nuisance.

Land
Effective
Indefi-
nitely.

“There seems no reason to doubt that, with proper management, land can purify sewage for a practically indefinite period. We are of opinion that sewage, before it is applied to land, should be efficiently screened and settled, unless it is already in a thoroughly disintegrated condition.” (Part I., page 106.)

Cropping
Desirable.

“Although we are of opinion that sewage farms in general can never be expected to show a profit if interest on capital expenditure is included, the fact that in favourable seasons some of them can more than cover the working expenses is a point in favour of cropping in connection with the land treatment of sewage. Moreover, in our opinion, cropping makes for purification, given good management, a volume of sewage not out of proportion to the average area under sewage at one time, and a suitably large ‘resting’ area. We are not in favour of sewage farms being let; unless the irrigable area is very large a tenant must sometimes be placed in the awkward position of having to choose between damaging a crop on the one hand and purifying sewage imperfectly on the other. It is impossible to lay too much stress on the importance of farms being well managed; but in this connection we

Letting
Inadvis-
able.

Manage-
ment—
Importance
of Good.

desire to state that farm managers have usually a most difficult part to play, and no amount of care and attention will ever enable land of any kind to deal with a volume of sewage out of all proportion to the effective purifying area of the soil. We recommend that farm managers should be taught some simple test, or tests, to enable them to follow for themselves the operations of the land; that their instructions should be in writing, and should include a definite order to consider the farming results as quite secondary to ‘turning out’ uniformly a satisfactory effluent; that the statistics of the farm should be most carefully kept; and that, wherever possible, the flow of sewage and of storm water should be gauged throughout the year. In the case of all large sewage works permanent provision should most certainly be made for recording, by some reliable method of gauging, the daily flow of sewage.” (Part I., page 107.)

Written
instruc-
tions—Pur-
ification
Sole Aim.

Gauging.

The difficulties which are frequently encountered on sewage farms in dealing with the normal dry-weather flow are so great that it is altogether impracticable to consider the treatment of six times this quantity with a view to securing an equal degree of purification. “Assuming, however, the possibility and practicability in all cases of a volume equal to six times the dry-weather flow being brought to the farm, we consider that the difficulty of treatment would be lessened by (1) increasing the capacity of the settling tanks; (2) having a larger ‘resting’ area (*not*, however, at the expense of the ‘working’ area, but by enlarging the total irrigable area); and (3) in particular cases by laying out portions of the land in special ways—*e.g.*, lagoons, storm-water filters, &c.—which need not be described here, since these matters would be determined by the local conditions . . . In this connection we desire again to emphasise the fact that neither chemically nor bacteriologically is mere dilution synonymous with purification. Granting the impracticability of treating more than a certain proportion of storm water, it should be definitely understood that storm water is diluted, not purified, sewage.” (Part I., page 109.)

Storm
Water.

“We have already expressed our opinion that the data available are insufficient to enable us to give any definite statement as to the best rate of intermittency either as regards filtration or surface-irrigation farms. By ‘rate of intermittency’ is

Intermit-
tency.

Land Treatment of Sewage.

meant, of course, whether the alternate periods of working and resting the land should occur at short or long intervals. It is obvious that if the alternations be too frequent the 'resting' area may not have time to recover its full purifying capacity before it is again sewage-d, and, on the other hand, if the alternations be too infrequent the 'working' area may be rendered sewage-sick; meanwhile the 'resting' area would be lying idle, long after it had recovered its purifying ability. A competent manager finds out by experience the best way of working the farm under his care; but it is desirable that the matter should be investigated experimentally, so as to enable certain general rules to be laid down for the preliminary guidance of persons responsible for the management of sewage farms." (Part I., page 109.)

The following remarks are made with regard to filtration:—

Filtration.

"(1) Excellent results can be obtained from light loamy soil overlying a porous subsoil. (2) A sandy soil and subsoil are also capable of yielding good results. (3) The same may be said of a partially peaty soil overlying gravelly sand. (4) Peat pure and simple is not well adapted for sewage purification. (5) With regard to chalk we can hardly speak with confidence, more data being required. The few (artificially obtained) effluents which we examined from a chalk farm had percolated in about a minute and a half through approximately 3 ft. of chalk (from which the surface soil had been removed); in so doing they had undergone comparatively little purification organically, although the liquid in its passage dissolved out a large quantity of nitrate—the product, no doubt, of the oxidation of sewage matter* run on at a previous time. The purification would, of course, have been better had the surface soil also taken its part. But the above very rapid rate of filtration of sewage through the fissured chalk emphasises the necessity for carefully considering any possible connection that may exist between a sewage farm on chalk and a water supply.

Surface Irrigation and Combined Surface Irrigation and Filtration.

"Heavy loam and clay soils, although not so well suited for sewage purification purposes, may, in our experience, yield fairly good effluents if the volume of sewage treated per acre is relatively small.

"Thus, almost any kind of soil can be used for the purposes of sewage purification, provided, of course, that the volume is proportionate to the purifying capacity of the soil in question. In certain cases, no doubt, this volume would be so small as to render

* "Whether this nitrification had gone on solely in the surface soil or also in the chalk itself we cannot say."

the particular method of treatment impracticable, but where the line should be drawn it is difficult to say. The price of land and other local conditions must needs influence this question of practicability. We are far from advocating the treatment of sewage upon land which is, practically speaking, not well suited for the purpose; but this does not invalidate the truth of the proposition—that the matter is nearly always one of degree of suitability, and seldom one of intrinsic disability. In reference to this we would lay stress on the good quality of the best effluents obtained from the eight sewage farms kept under detailed observation." (Part I., pages 110 and 111.)

"To summarise all our results within the limits of a few sentences is impossible, but we may say in conclusion, and speaking in general terms, that we doubt whether even the most suitable kind of soil worked as a filtration farm should be called upon to treat more than 30,000 to 60,000 gallons per acre per twenty-four hours at a given time (750 to 1,500 persons per acre), or more than 10,000 to 20,000 gallons per acre per twenty-four hours, calculated on the total irrigable area (250 to 500 persons per acre). Further, that soil not well suited for purification purposes, worked as a surface irrigation or as a combined surface irrigation and filtration farm, should not be called upon to treat more than 5,000 to 10,000 gallons per acre per twenty-four hours at a given time (125 to 250 persons per acre), or more than 1,000 to 2,000 gallons per acre per twenty-four hours, calculated on the total irrigable area (twenty-five to fifty persons per acre). It is doubtful if the very worst kinds of soil are capable of dealing quite satisfactorily even with this relatively small volume of sewage. The population per acre is calculated on 40 gallons of sewage per head per day. It is here assumed that the sewage is of medium strength, and is mechanically settled before going on to the land.

"Comparing the above figures with the volume of sewage capable of being treated by artificial processes, we note that the witnesses examined by the Commission generally expressed the following opinion:—

"750,000 gallons per acre per twenty-four hours, allowing for periods of rest, but not for secondary treatment. Allowing 1 acre of secondary bed for every 2 acres of primary bed, about 500,000 gallons per acre per twenty-four hours could, according to this view, be finally treated. It is assumed always that the sewage has been previously treated, either by chemical precipitation or by subsidence in settling tanks, or in a septic tank.

"About 484,000 to 2,904,000 (4,840,000 according to one witness) gallons per acre per twenty-four hours. Previous treatment by chemical precipita-

Area Required.

Contact Beds.

Continuous Filters.

General Conclusions.

tion, or subsidence in settling tanks, or in a septic tank, is assumed.

"Apart from the question of the quality of the effluents it is obvious that, generally speaking, a larger volume of sewage can be treated by artificial bacteria-bed processes than by land." (Part I., pages 113 and 114.) "Effluents from land usually yield more variable results than effluents from bacteria-bed processes of sewage treatment." (Part III., page 19, footnote.)

"It is impossible to lay down any hard-and-fast rule as regards the proper proportions between the area actually being irrigated at one time and the

should be 5,000 gallons per acre per twenty-four hours for an irrigation farm and 30,000 gallons for a filtration farm. Allowing 40* gallons of sewage per head per day, this works out to 125 and 750 persons per acre respectively. On the basis of population, other witnesses gave 100 to 1,000 persons per acre as the working limits, the number varying with the process of treatment adopted, the nature of the soil and other factors. Converted into volumes of sewage per head per twenty-four hours (at 40 gallons per head), this gives 4,000—40,000 gallons per acre. Others, again, suggested the following figures for population per acre:—

Proportions—
Working
and
Resting
Areas.

PERSONS PER ACRE.			
—	Crude Sewage.	Precipitated or Mechanically Settled Sewage.	Sewage after Preliminary Treatment on Bacterial Filters.
Surface irrigation ...	50—100	100—500	300—1,000
Filtration... ..	75—150	200—500	400—1,000

surplus ('resting') irrigable area. Each case must be judged on its own merits, but broadly speaking

Again assuming 40 gallons of sewage per head per day, the above figures may be expressed thus:—

GALLONS OF SEWAGE PER ACRE.			
—	Crude.	After Precipitation or Settlement.	After Bacterial Filters.
Surface irrigation ...	2,000—4,000	4,000—20,000	12,000—40,000
Filtration	3,000—6,000	8,000—20,000	16,000—40,000

the tentative assertion that at least (a) four-fifths of a surface irrigation farm and (b) two-thirds of a filtration farm respectively should be at rest is probably not remote from the truth, it being assumed that (a) one-fifth and (b) one-third are capable of effectively purifying the sewage until such time as the next one-fifth and one-third respectively of the surplus irrigable area, due in rotation, have been sufficiently rested. The above is subject to the reservation that the whole question of intermittency is but little understood, and, as we have said before, whether or not rapid or slow alternations of working and rest are advisable we are unable to say." (Part I., page 17.)

"A divergence also showed itself in the opinions of witnesses with respect to the question of population and of volume of sewage allowable per acre. Some of them considered that the maximum limits

Broadly speaking, therefore, the various witnesses examined placed the extremes at 50 persons or 2,000† gallons per acre per twenty-four hours, and 1,000 persons or 40,000 gallons per acre per twenty-four hours." (Part I., page 111.)

"Without making any definite or final statement on the subject at present, we think it would probably be found that any effluent which did not within the twenty-four hours after drawing take up more than about 3 c.c. to 4 c.c. of oxygen per litre (when kept in a full bottle at, say, 18 deg. C. or 65 deg. Fahr.) would be found to be chemically satisfactory.

Chemical
Tests and
Standards.

* "This figure of 40 gallons is taken because it was the average volume at the eight principal sewage farms kept under observation. According to some statistics collected recently by our colleague, Mr. Colin C. Frye, it is probably not far from the mean for towns and cities with a population of 10,000 to 100,000 and over, though much too high for small towns and villages. It is brought forward here for comparative calculations only."

† "It is difficult to see how this small volume could be satisfactorily spread over an acre of ground."

Witnesses'
Figures.

Land Treatment of Sewage.

The test might have to be taken in conjunction with the permanganate 'oxygen absorbed' test, to provide against the (unlikely) contingency of an effluent being a sterilised one; and in the present state of our knowledge it might also be advisable to safeguard it further as regards a maximum of nitrogenous organic matter to be allowed in any effluent at any time (measured, say, by the aluminoid nitrogen), though this additional precaution might in the end be found unnecessary. We think there can be no doubt that, if it could be satisfactorily and easily worked out in practice, a standard based upon the above principles would deal equably between effluents from strong and weak sewages, not favouring the one at the expense of the other." (Part I., page 65.)

The following extract from Mr. Dibdin's book (which has already been mentioned) agrees very closely with the above suggestion. "The exact degree of aeration which an effluent thus kept should maintain is a matter for further experience to determine; but if it does not fall below 50 per cent of the maximum possible, no evil results need be apprehended. Whenever the aeration of the water of the Thames was found to exceed this minimum there was no suggestion of nuisance, and fish appeared in the areas which maintained this degree of aeration. If, then, an effluent be added to water in quantity exceeding that which would actually be the case in practice, and the degree of aeration at no time falls below the point indicated, fish-life would be in no way interfered with. Further, the power of a river to purify itself depends upon the degree of aeration maintained; and when this exceeds the figure above mentioned there is not the least fear of putrefactive processes intervening, but aerobic purification continues, and all remaining organic matter is rapidly oxidised. A most valuable standard of purity might be arrived at by these means. Suppose, for example, that a mixture of one part of effluent and one part of fully aerated water be allowed to stand in an open vessel of diameter equal to the depth of the liquid, and that the degree of aeration, ascertained daily for a certain number of days, does not fall below an agreed figure to be determined, then such effluent may be safely admitted into any ordinary stream. In extreme cases, when the only water in the brook is derived in summer time solely from the sewage works, the effluent must of course stand the test without any dilution." (Pages 297 and 298.)

Dr. Houston gives the following summary (Part III., pages 187 and 188): "Some diffidence is felt in briefly summarising the foregoing conclusions. It

is assumed that what follows in the way of summary will be interpreted in the light of my more detailed and guarded statements, and only accepted as valid subject to the qualifying remarks and reservations that have been previously brought forward.

(1) The treatment of sewage on land (with the apparent rather than real exception of Nottingham) does not so modify the biological qualities of sewage as safely to admit of the direct discharge of the effluents from land processes into drinking-water streams.

(2) The bacterial flora of the soil on sewage farms is apt to resemble that of sewage plus in a greater or less degree the microbes characteristic of soil.

(3) With regard to the ultimate fate of sewage microbes sown broadcast on soil, a gradual destruction (relative, if not absolute) of the bacteria of non-sporing and adventitious sort seems to ensue when the application of sewage to the soil is discontinued.

(4) The bacterial flora of effluents from land processes of sewage treatment is characteristic of the bacterial flora of sewage, not of soil.

(5) The average percentage reduction in the total number of bacteria and in the number of *B. coli* and spores of *B. enteritidis sporogenes* in the land effluents as compared with the sewage is striking.

(6) The best effluents from the different sewage farms were remarkably modified in the direction of purity, and easily satisfied my suggested bacteriological standards for effluents destined to discharge into non-drinking-water streams.

(7) The average biological quality of the effluents from the sewage farms, excluding Nottingham, was not *entirely satisfactory* according to my bacteriological standards (non-drinking-water streams). Nevertheless, generally speaking, the effluents came within measurable distance of 'passing' the primary and nearly always passed successfully the secondary standards which have been provisionally adopted for working and comparative purposes.

(8) It is extremely difficult for many reasons to compare either (a) land filtration with 'surface irrigation' or (b) land eminently well suited for sewage purification processes with land less suitable or of unsuitable sort. Thus as regards (a), surface irrigation is commonly combined with some filtration, and in respect of (b) suitable land is usually sewaged to a much greater extent than unsuitable land; consequently in the resultant effluent differences are *masked* which otherwise might be very apparent. Of course, in point of fact, (1) filtration and suitable land, and (2) surface irrigation and unsuitable land, are usually correlated conditions. There was no comparison between the effluents from

General Conclusions.

Nottingham (light loamy soil, 'filtration' effluents) and the effluents from the sewage farms treating sewage in the main by surface irrigation over heavy land. But it is satisfactory to note that surface irrigation effluents from heavy clay soil may, under favourable conditions of working the land, yield reasonably good effluents.

(9) The treatment of sewage on land, as compared with its treatment by artificial processes, is a matter which is still under investigation, and therefore no definite pronouncement can here be made. But, speaking solely from the bacteriological point of view, land (if of suitable sort for sewage purification purposes and properly worked) is, in my opinion, to be preferred to artificial processes as now conducted.

(10) The *intrinsic* biological qualities of sewage are not materially modified by land processes of sewage disposal, as judged by the tests employed in this investigation.

(11) Samples of water derived from the rivers or brooks into which 'land effluents' are being discharged were usually found *above the effluent outfalls* to be impure (sometimes very impure) on bacteriological examination.

(12) The biological quality of a few samples of the subsoil water in the neighbourhood of sewage farms was determined. The results, as a rule, were satisfactory, but the samples were not examined in the exhaustive manner necessary when the question of potability is involved.

(13) If the examination of 'storm overflow liquid' be interpreted in the light of the confirmatory results which were subsequently obtained, it would seem that 'storm overflow liquid' is *potentially* as dangerous as undiluted crude sewage.

(14) 'Street washings' liquid (separate system) may be a grossly impure liquid from the bacteriological point of view."

AUTHOR'S SUMMING-UP.

A comparison of the various farms dealt with in the reports of the Royal Commission on Sewage Disposal is hardly possible—the circumstances differ so widely that it may almost be affirmed that in no two respects do any two farms resemble one another. The chief value of the investigation, in my opinion, lies in the exhaustive manner in which the information with regard to each farm in turn has been presented. I would again draw attention to the light thrown on the work accomplished in or on the land by the discoveries that have been made of late years in the domain of bacteriology. It is no small step forward to have passed from a vague notion of "oxidation" to a realisation of the processes occurring during the purification of sewage; to an appreciation (imperfect though it may be) of the activity of the micro-organisms which are so largely concerned in this connection. I trust that the condensation and re-arrangement* of the material to be found in the 787 pages of the four reports will be of service to those who, though dealing with the vitally important subject of the disposal of sewage, have not, on account of their manifold duties, leisure sufficient to peruse and digest the blue-books in question. I do not propose to say much by way of final summary, but would direct notice to some few points.

Sewerage is a matter of engineering, and so is

* The order of the farms and the particulars detailed are by no means uniformly set out. The value of the reports would have been enhanced had they been provided with cross-references and been subjected to efficient "editing."

sewage disposal to a large extent. The first item to be considered is the destination of the effluent, and when this has been settled (either definitely or provisionally for alternative schemes) the degree of purification needed can be ascertained within rough limits. Such questions as the adoption of the separate, partially separate, or combined system of drainage, the inclusion of manufacturing effluents, the provision of storm overflows, &c., are dependent on local conditions. At the same time the mode of treatment must be borne in mind and all stages preliminary thereto—*e.g.*, detritus chambers, screens, pumps (if necessary) and settling tanks. The disposal of screenings and of sludge must be kept in view, especially when a proposed site is not so extensive as might be desired. If the sewerage and adjuncts can be likened to the woof, the disposal of the sewage may be regarded as the warp—the two being essential parts of the whole.

The treatment of the sewage is a mere matter of money—it can be done in one of a variety of methods. The rival claims of sewage farms and bacterial installations (and possibly, also, of chemical methods) have to be judged by the circumstances of the neighbourhood—the nature, extent and price of the land available, the cost of material suitable for bacteria beds, &c. It is at this stage, more particularly, that an extensive acquaintance with the subject is essential if due economy and efficiency—the maximum of result for the minimum of expenditure—are to be obtained. Suffice it to say that the

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advocate of no one system is in a position to judge dispassionately of the merits of his own as compared with other schemes. It may well be that the results from his particular method of treatment will be eminently satisfactory from the purification standpoint; but it is possible that a like success might have been achieved at less expenditure by some other system.

In the case of the improvement of existing sewage works the problem is much less complicated. Effluents may no longer pass muster, on the one hand, because of the extra burden due to increased population and extended or additional industrial activity, and, on the other hand, on account of the greater degree of purification now enforced—in some instances both causes may have contributed to the result. It is interesting to note what has been done at the eight selected farms in this respect. At Aldershot Camp the water supply has been reduced and the farm is unchanged; Altrincham and Nottingham have extended their boundaries; Cambridge is turning the plots into "bacterial areas"; Croydon, Leicester and South Norwood have adopted preliminary bacterial treatment (the works at Leicester being designed to effect a purification of 71 per cent before the land is utilised); and Rugby has a scheme in hand, rendered necessary by the diminution of the area available, though even had that not occurred additional accommodation would no doubt have been required. It would have been very instructive had the Corporation of Croydon attempted to use the land at Beddington as a filtration farm.

The Local Government Board's (England) sanction to a loan for sewage treatment is usually conditional upon the purification of six times the dry-weather flow, three volumes as sewage proper and three volumes (less efficiently) as storm water. At the date of the reports Aldershot Camp (separate), Altrincham (combined) and Nottingham (combined) treated very little; Cambridge (partially separate) a small amount; Leicester (combined) two and a half times the dry-weather flow; Rugby (partially separate) nearly all; and Croydon (partially separate) and South Norwood (partially separate) all from the sewers. When the flow is greatest the land receives most extra water in the form of rain, and as a rainfall of 1 in. represents 22,620 gallons per acre the burden on land as compared with bacteria beds, where such an amount would be a negligible quantity, is a factor of no mean importance.

The additional information afforded upon the

character of the soils and subsoils in use or likely to be used for sewage disposal is most welcome. The tables of "mechanical analysis" are the more useful as they indicate where so many errors of judgment have in the past been committed. The late Mr. Bidder is reported to have said on one occasion, when referring to the regulations of the Local Government Board, that he supposed an acre of ducks' backs would be treated exactly like an acre of road metalling or porous gravel. One instance may be quoted in support of Mr. Bidder's contention, and it is taken from the evidence given to the Commission on January 19, 1899, by Dr. Sidney Barwise, county medical officer of Derbyshire. "I say this stiff clay land cannot act as an intermittent filter. Loans are sanctioned to lay it out for intermittent filtration, and it is laid out, but it is a physical impossibility to filter through material which is used to puddle the banks of reservoirs with. Brampton is a case in point of what is called intermittent filtration; the loan was sanctioned for intermittent filtration, and the only way the sewage goes through the clay is through the worm-holes and the cracks as I have described." The sewage is not treated before it is applied to the land. Care must be exercised to guard against the pernicious habit of considering only one or two factors in the complicated question of sewage disposal. A soil, comparable to one of those reported on, may not be able to accomplish more than a fraction of the purifying power recorded—the sewage may differ in strength and in amount and the volume of storm water to be treated may be many times as great.

We still await the final report of the Royal Commission on Sewage Disposal, which will deal *inter alia* with the extremely valuable reports forming the subject of these articles. Sewage farming is beset with many difficulties, and some of these must have been apparent to my readers even if they were not personally acquainted therewith beforehand. It may be said without fear of contradiction that where the soil is suitable, the flow not overmuch, and the management competent, a sewage farm can produce excellent results. To what extent alterations should be made to existing farms where inefficient, and land should be employed at new outfalls are matters that depend entirely upon local conditions. It is only when these have been ascertained and have been duly considered by an independent expert that the true solution of the particular problem in question can be obtained.



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